DIMENSIONS NBS

The magazine of the
National Bureau
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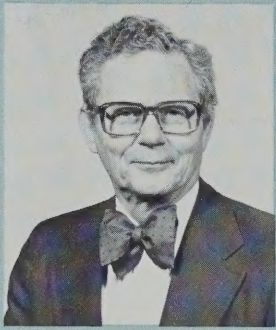
GYROMAGNETIC RATIO. See page 10.

COMMENT

REFINING PHYSICAL STANDARDS



The article on the accurate redetermination of the proton gyromagnetic ratio (γ_p) and the fine-structure constant (α) by P. Thomas Olsen and E. R. Williams which appears in this issue of DIMENSIONS/NBS is representative of an important aspect of the research program in the National Bureau of Standards' Center for Absolute Physical Quantities (CAPQ). Fundamental physical constants such as γ_p and α are the units in which physical measurements must ultimately be expressed if we are to establish an invariant measurement system. Furthermore, they must be measured to the highest possible accuracy in order to determine the validity of the laws of nature that we postulate.

The principal mission of the Center for Absolute Physical Quantities is the development, maintenance and dissemination of the primary physical standards. In order to do this effectively, we must work with maximum skill and ingenuity at the forefront of measurement capability. The skills we have developed give us an excellent opportunity to perform definitive measurements of constants such as γ_p and α. Similar experiments now under way or recently completed within the Center include accurate determinations of the Newtonian gravitational constant, the speed of light, Avogadro's number, the Faraday, the gas constant, and an improved test of Einstein's theory of the isotropy of space.

A major responsibility of the CAPQ is to assure the U.S. an accurate and accessible physical measurement base for the units of length, mass, temperature, time, frequency and electrical quantities. Of the basic units involved (the meter, kilogram, degree kelvin, second and ampere), only the kilogram is defined in terms of an artifact standard. The remaining units are defined by natural constants or physical laws.

As science and technology advance, new definitions and measurement techniques must be developed to meet ever more stringent needs. Such a change currently under way is the redefinition of the meter in terms of the speed of light. At the NBS laboratories in Boulder, Colorado, pioneering work on the measurement of frequencies in the optical range (5×10^{14} Hz) now makes such a definition practical. The crucial experiment was originally conceived as a new determination of the speed of light by measuring both the frequency and the wavelength of radiation from a stabilized laser. Having achieved this to an accuracy limited only by the current definition of the meter, we then suggested that the derived value of the speed of light be a defined constant and that the definition of the meter be based upon wavelengths of stabilized laser radiations obtained by measuring their optical frequency and multiplying that frequency by the speed of light. That new definition has been endorsed by the Consultative Committee for the Definition of the Meter for consideration by the General Conference on Weights and Measures.

In order to maintain an accurate and consistent measurement base for U.S. science and technology, the CAPQ carries on research programs that tax our precision measurement capability to the limit. We aim to improve both the national measurement base and our knowledge of the physical world.

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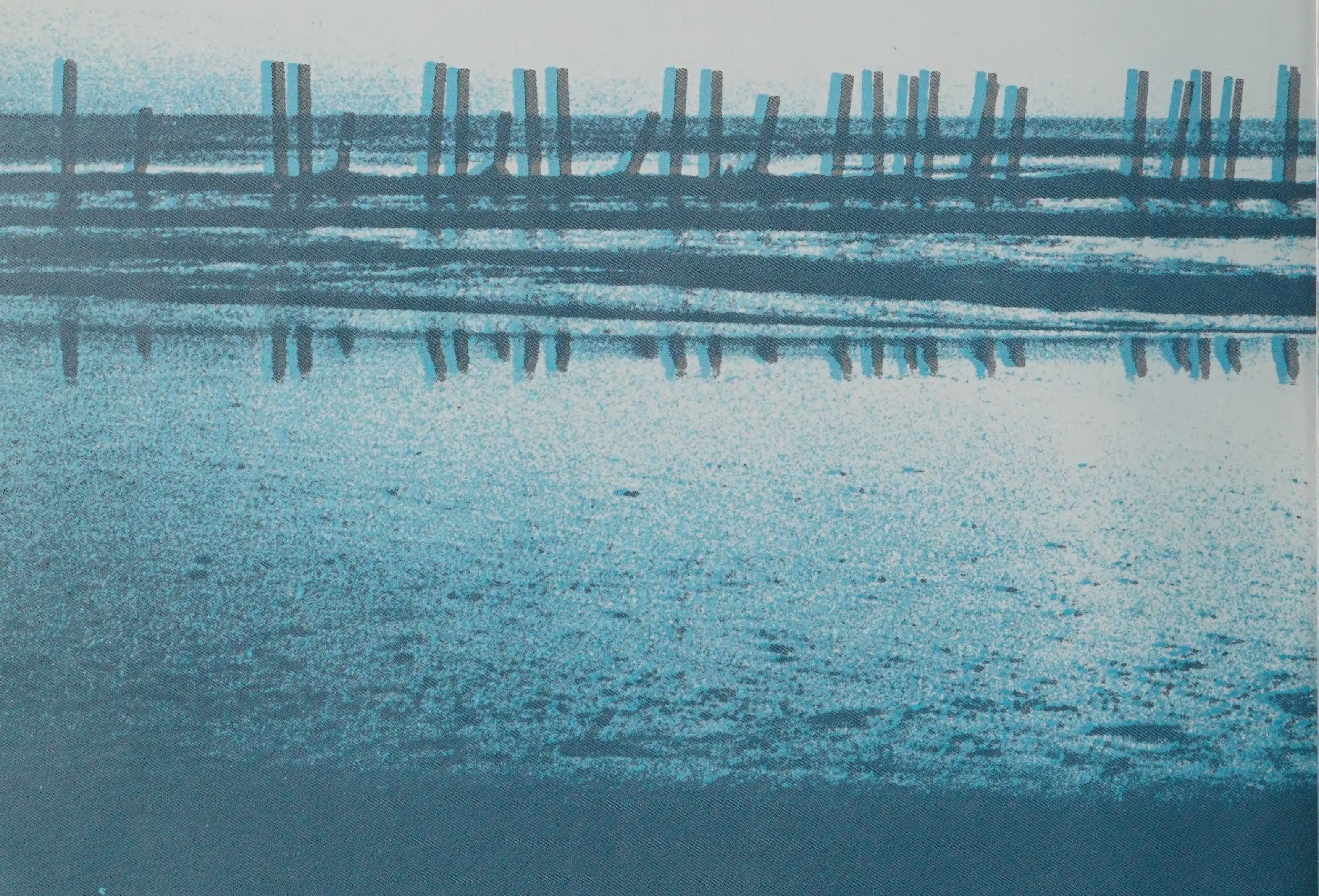
MEETING MOTHER NATURE ON HER OWN TURF

MONITORING CORROSION IN THE FIELD



by Gail Porter

Just as there is no substitute for Mom's apple pie, or gen-u-ine leather, there is often no substitute for research carried out in the field. Although lab scientists continually strive to impersonate Mother Nature, duplicating the complex factors which make up the environment is a difficult, and sometimes seemingly impossible, task.

In the area of corrosion research, lab scientists have been instrumental in explaining the whys and wherefores of corrosion processes, and hope someday to have tests which fully simulate corrosive environments. But so far, the pitting of specimens against the brute forces of rain, wind, and soil has often been the best source of reliable judgements of long-term corrosion resistance.

At the National Bureau of Standards, corrosion researchers have been meeting Mother Nature on her own turf for over 50 years. Through measurements made at field sites, and the development of new nondestructive measurement methods, they hope to provide industry with ways of locating corrosion in power cables, reinforcing bars, supportive steel pilings and telephone lines and steel piping systems.

"The goal of the corrosion field testing program," says Thomas Coyle, chief of the Bureau's Chemical Stability and Corrosion Division, "is to provide data on the performance of materials in their service environments and to develop measurement methods to detect corrosion 'in situ.' Our current strategy is to augment traditional field studies by applying modern scientific concepts and data processing techniques. In the long term, we hope to identify critical elements in the corrosion process so that accelerated laboratory methods may be developed. Ideally, we would like to have test methods which

Porter is a staff writer for DIMENSIONS/NBS.

can be performed in the laboratory to tell us in 10 minutes what the corrosion resistance will be like in 10 years."

The need for such methods becomes immediately apparent when the dollars and cents aspects of corrosion damage are examined. According to a report issued last year by NBS and the Battelle Columbus Laboratories, the cost of corrosion in the United States was a mountainous $70 billion during 1975 and that figure is still climbing. To combat this problem, U.S. industry spends an estimated $217 million annually in corrosion research, and the Federal Government, approximately $40 million.

Corrosion at NBS

The Bureau's Chemical Stability and Corrosion Division accounts for a small but significant part of this Federal corrosion research effort. In particular, says Coyle, the NBS Corrosion Field Testing Program represents one of the oldest and most diversified efforts to study corrosion processes in natural environments. Since 1911, Bureau researchers have designed field testing experiments and measurement methods to meet the needs of industry as new products and new applications for old ones present additional corrosion problems.

For instance, one of the Bureau's first major field testing projects involved measurement of the corrosiveness of different kinds of soils. The project continues to the present day, but over the years the emphasis has shifted from measuring the corrosion resistance of such metals as cast iron and copper to measuring the resistance of modern stainless steels and sophisticated aluminum alloys. The corrosion field measurement methods have also advanced from simple visual inspection of corrosion damage to the use of sensitive electrochemical techniques.

Corrosion: Causes and Prevention

Corrosion is the destruction or "eating away" of metal due to its exposure to various environments, particularly moisture. Corrosion can cause holes, cracks, or thinning of metal objects making them unsafe or useless.

The reason metals corrode has to do with their atomic makeup. With the exception of gold, all metals occur naturally in combination with other elements or ores. A metal which must be "pulled" from its ore, will tend to revert to its natural form by corroding. Corrosion, then, is the process of a metal combining with chemicals in the environment to form compounds more like the stable ore from which it was derived.

Some metals are more susceptible to corrosion than others. Gold, graphite, silver, and stainless steels are very corrosion resistant. Bronze, copper, brass, tin, lead, and lead-tin soldering material are moderately resistant. In general, cast iron, ordinary steel, aluminum, zinc, and magnesium are less resistant than these other metals.

Not all corrosion takes the same form. *Galvanic* corrosion occurs when two different metals in contact with each other are exposed to wet, corrosive environments such as salt water, bleach or detergent. *Crevice corrosion* takes place when corrosive chemicals build up under a portion of the metal object which is covered with dirt, a gasket, bolt, or rivet heads. *Pitting corrosion* results when a very small bare metal area is attacked by corrosive chemicals causing holes or "pits." *Stress corrosion* occurs when a metal that has been pulled or bent in the manufacturing process is exposed to corrosive environments. This type of corrosion may cause the metal object to crack at a bend.

There are four basic approaches to corrosion prevention. These include: choosing metals which perform particularly well in certain corrosive environments; applying coatings such as paints, greases, waxes, lacquers, or varnishes to protect the metal; adding chemicals called inhibitors to the environment around a metal or applying the chemical directly on a metal object to lessen the corrosiveness of that environment; and coupling a less corrosion resistant metal such as zinc with a more resistant one such as steel. The zinc in such a "cathodic system" will protect the steel while accelerating its own corrosion.

For more information on corrosion and its "cures," send for "Corrosion, Facts for the Consumer," an NBS consumer guidebook made available through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, (price, 80 cents). Use stock number 003-003-01947-0.

At a field test site near Loch Raven Reservoir, Baltimore, MD, NBS researchers work with employees of the local water department to bury samples of telephone cable materials.

"Originally," says Jerome Kruger, head of the present Corrosion and Electrodeposition Group, "NBS had about 120 soil corrosion field sites all over the country." The corrosion researchers responsible for this work "were on the train all the time" visiting the sites, testing methods for determining corrosion rates of various samples of metal, and extracting specimens from the soil after specific years of exposure for laboratory examination.

The first NBS corrosion researchers, adds materials research engineer William Gerhold, would bury metal test specimens "wherever they could find a vacant lot."

Based on this early research, six different kinds of soils were selected to represent the bulk of soil types throughout the country. The six underground corrosion testing sites currently in use contain some specimens more than 20 years old.

These sites are located in Washington on the Yakima Indian Reservation; in Maryland, near Baltimore at a reservoir operated by the local water department, and at the Patuxent U.S. Naval Base along a tributary of the Chesapeake Bay; in New Jersey at two Coast Guard bases, with one test site at Cape May and two others at Wildwood.

At each of these sites the Bureau has been provided land for testing purposes free of charge, and, in some cases, receives additional support through the use of personnel and equipment needed to bury and extract samples.

Presently, the six sites contain samples of cables used or considered for use in underground telephone lines and of the various types and forms of stainless steel that may be used in underground applications. Some of these applications include transformer cases for underground telephone and power supply, water or gas pipelines, and sewage disposal systems.

A cast iron pipe sample is retrieved from the "jaws" of a back hoe.

Corrosion by Soil

The corrosion of underground telephone cables has only become a problem during the last 10 to 12 years. "Most of the utilities," says Gerhold, project

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leader of both the telephone cable and stainless steel studies "have had to go underground" as the number of aerial lines increased and demands were made on companies to preserve the aesthetic appearance of the land.

The Rural Electrification Administration (REA), responsible for the regulation of telephone and electrical utilities in less developed areas of the country, asked the Bureau about 10 years ago for research on the performance of cables intended for underground use. These cables typically consist of a central bunch of current-carrying wires shielded by a layer of metal which, in turn, is jacketed with an insulating material such as polyethylene, a durable plastic. The REA needed information on the corrosion resistance of the shielding material intended to keep extraneous electricity from interfering with telephone conversations carried through the central wires.

Even though these cables are normally protected from corrosion by the polyethylene covering, physical damage caused during installation by lightning or even by cable-munching gophers can often leave the shielding material exposed. Before NBS began research in this area, the utilities had been using copper, a very good electrical conductor which is naturally high in corrosion resistance, for both the current-carrying wires and the shielding material.

"Copper was getting pretty expensive," says Gerhold. "They wanted to come up with a material

Technician James Fink removes the polyethylene covering from mud-caked telephone cable samples to examine the corrosion damage to the ridged shielding metal inside (see foreground).

Materials research engineer William Gerhold and Fink install new telephone cable housings which will be monitored for corrosion resistance.

that would be corrosion resistant and still be reasonably priced."

In 1968, 1086 samples of 12-inch cable sections representing 31 different types of cable were buried at each of the six field testing sites mentioned above. Most cable samples contained "windows" where the protective polyethylene jacket was stripped to expose sections of the shielding metal.

At regular intervals, members of the NBS corrosion group visit the test site and extract cables. The shielding metals are cleaned and then visually examined to determine the extent of corrosion damage. The type of corrosion found, whether general or localized, as in pitting, is also noted. Based on the findings of six consecutive years of measurement, NBS submitted recommendations to REA.

As a result of the Bureau's research, REA has rewritten specifications for telephone companies under its jurisdiction which allow some metals and metal combinations to be used in cables while prohibiting others with less corrosion resistance.

This project has been expanded each year, says Gerhold, with the addition of new types of cables as they become available. To date, over 70 different cable systems have been buried at the six sites.

In 1970, the Bureau initiated a similiar field testing project with the American Iron and Steel Institute to measure the corrosion resistance of various types and forms of stainless steel. Although stainless steel is usually referred to in singular form, there are many different kinds with widely ranging price tags depending on the proportion of chromium, nickel, or molybdenum in the alloy.

Over 1000 specimens were buried at each of the six sites used for the telephone cable project. In addition to removing and examining the specimens at intervals, the researchers have also used a nondestructive technique called electrochemical polarization to measure the corrosion rate of stainless steel samples.

Electrochemical Measurements

Electrochemical polarization makes use of the fact that corrosion is a type of electrical process*. As surface metal atoms react with chemicals in contact with them, small amounts of electricity called corrosion currents are created within the metal. The currents result from the flow of electrons between negatively charged sections of the metal (anodes) and positively charged ones (cathodes). The positively charged areas are caused by the action of oxygen and water pulling electrons away from neutral metal atoms, while the negatively charged areas occur when the corroding metal is removed, leaving free electrons.

By applying an electrical current to a piece of corroding metal, the tendency of the metal to corrode may be temporarily altered. This change in the tendency to corrode is called polarization. If a large current is required to polarize a metal being tested, then the corrosion current is large and the metal is corroding rapidly. If a small current is sufficient to polarize a metal, then the corrosion current is small and the metal is corroding slowly.

Repeated measurements made over the lifetime of the specimens allow the researchers to draw a profile of corrosion at different intervals over extended periods of time. These profiles are important for judging the usefulness of various kinds of stainless steel for different purposes. For example, one type may provide satisfactory corrosion resistance for the first five years of use but its protective characteristics may deteriorate rapidly after that point. If replacement of the part at this interval is more economical than initial use of a more durable and more costly stainless steel, then this may be the best stainless steel available for certain applications.

The major finding of the Bureau's field work with telephone cable and countless forms of sheet and piping metals has been the discovery that no one type of metal or protection system seems to be totally effective in all types of soil. Instead, the chore of selecting corrosion resistant materials is a complex one which depends on the intended use of the material; its form such as wire, piping, or welded sheets; the type of soil in which the material is buried; and a myriad of other environmental factors.

Corrosion of Steel Piles

In many cases, the selection of NBS field sites and projects stems from requests by organizations outside the Federal Government. A field test site in Montreal, for example, resulted from concerns of a Canadian highway construction firm about the corrosion resistance of the steel piles supporting an intricate highway interchange system in particularly corrosive soil. In exchange for a test area at the interchange and the resources of the construction firm for the installation and removal of

The rust that ruins a wrought iron railing or causes a car to be retired before its time is a product of the process.

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A canopy provides relief from the sun as NBS scientists record the corrosion rates of each of the steel piles at the Dam Neck, VA, field site.

test pilings, the Bureau has monitored the corrosion resistance of samples at this site since 1966.

During that year, 30-foot steel piles of the type used to support concrete structures were either driven directly into the ground or buried horizontally at the Montreal site. Some of the 21 piles were coated with corrosion resistant paint, some were "capped" with concrete, and some were left bare. Every year since then researchers have visited the site and measured the corrosion rate of the piles using the polarization technique described above. In addition, some samples were removed after 3, 6, and 12 years of exposure and the extent of actual damage was determined by weighing and measuring the thickness of the specimens to see how much metal had been lost through corrosion.

Sponsored jointly by the Province of Quebec and the American Iron and Steel Institute, the project is slated to continue for 50 years from the year of installation.

This may seem an unusually long time for one research project by ordinary standards. However, corrosion is usually a very slow process. Field test projects often require more than a decade of measurements before conclusive results may be reported.

Electrochemical polarization techniques, for example, were first being applied to corrosion measurement around the early 1940's. But before the technique is given the seal of approval, the electrical measurements must show statistically reliable correlation with the evidence of actual corrosion damage which takes years to develop.

So far, says Edward Escalante, project leader of the Montreal study, the electrochemical polarization and the physical evidence of corrosion have matched very well. At Montreal, the electrical measurements have successfully portrayed the different corrosion rates for bare, coated, and capped piles.

Corrosion By the Sea

Other electrical measurements are being made at a U.S. Navy base at Dam Neck, Virginia, to determine the corrosion rates of over 80 piles treated with many different coatings and cathodic protection systems. The piles are driven into the sea floor about 100 yards offshore and look, to the unknowing observer, like the remains of a fishing pier. This project should provide valuable information on effective ways to measure corrosion rates of steel structures such as offshore oil rigs.

So far, about one third of the offshore piles have been removed and physical measurements of corrosion damage have been compared with electrical measurements. When the remainder of the piles are removed sometime next year, the comparison of physical and electrical data, combined with the results from the Montreal site, the stainless steel project, and a relatively new power cable project, should provide a long awaited measure of the reliability of the electrochemical technique.

Opposite page. The sun stretches a yawning ray through the 70 steel piles at the Dam Neck, VA, field test site.

Warren Iverson (left) adjusts the voltage applied to an offshore steel pile during electrochemical polarization experiment while Edward Escalante (center) and Benjamin Sanderson plot the results.

Corrosion of Underground Power Cables

Researchers will also be experimenting during the next 2 years with a new technique to detect pitting corrosion in buried power cables.

This type of corrosion has recently become a problem for electric power companies. The cables consist of current-carrying wires in the center, surrounded by a special kind of polyethylene plastic. The outside of the plastic insulator is wrapped with "grounding" wires. Corrosion damage to these outside wires can be very dangerous since they serve to protect anyone who accidentally digs up a cable from electrocution.

The new technique involves measuring small fluctuations of the corrosion current from its average value. These fluctuations are commonly referred to as "noise" and are thought to be larger when pitting corrosion is occurring.

In this new project, sponsored by the Electric Power Research Institute, NBS researchers will be using noise measurements and other electrochemical techniques to try to detect and locate corrosion on these grounding wires.

The job will certainly not be easy, says Escalante. "We are trying to measure a little twig (noise fluctuations) in a forest (overall corrosion current.)"

In the Future

Although the corrosion field testing program has a long history at NBS, it is by no means static. New corrosion problems continually pose new challenges.

A project recently begun with sponsorship by the Department of Energy will focus on monitoring the corrosion resistance of metals used in municipal incinerators. The need for cheaper forms of energy and the lack of space for adequate solid waste disposal have spurred the development of fuels processed from garbage. The combustion products of these refused-derived fuels are highly corrosive. New corrosion resistant materials must first be identified before refuse-fueled incinerators will be durable enough for long-term use.

Another new project involves the measurement of the corrosion of reinforcing steel used in concrete roadways, such as bridge decks. The emphasis here will be to develop easy-to-use polarization instruments. These same instruments may then be adapted to serve other corrosion monitoring functions.

Work is also under way to develop automated data acquisition and ultimately, microprocessor-controlled field measurements of corrosion and environmental data. When fully implemented, these new techniques will permit almost continuous monitoring of corrosion processes under a variety of field conditions. With these new tools, researchers will have powerful new weapons in their continuing war against corrosion. □

COVER STORY

THE PRECISELY PRECESSING PROTON

by Michael Baum

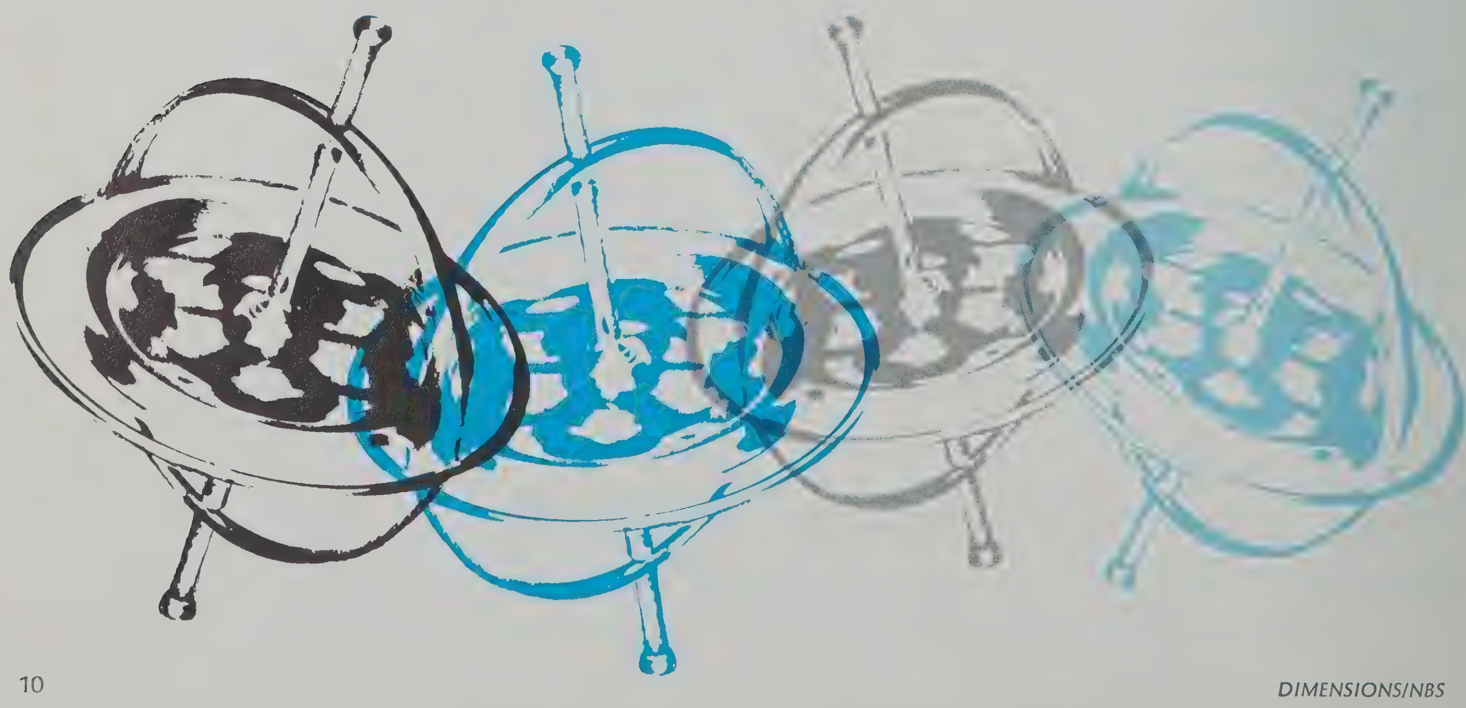
THIS article is on a topic with the obscure-sounding title of "the redetermination of the gyromagnetic ratio of the proton and the fine-structure constant." Before you ask what that has to do with anything, let us assure you that it has to do with everything.

In brief, earlier this year two NBS physicists, P. Thomas Olsen and Edwin R. Williams, published the cumulative results of several years of work leading to a new value for a basic constant of physics known as the fine-structure constant, α, measured to the unprecedented accuracy of one-tenth of a part per million (ppm).

In the words of Dr. Williams, "The measurement we made has a profound effect on one of the most fundamental theories of physics, and yet, interestingly, the experiment we did is fundamentally one of the most simple—measuring the distance beteen two wires."

But before all this makes sense, we will have to back up a bit.

Baum is a writer and public information specialist in the NBS Public Information Division.



IMPROVING THE GYROMAGNETIC RATIO AND OTHER CONSTANTS

The "basic physical constant" involved in this work appears in many equations and theories of modern physics, but for our purposes the most important thing is that it is central to a theory in physics known as quantum electrodynamics, or QED for short.

QED is perhaps the most successful physical theory produced by physics to date. In fact, because of these successes ". . . it is now believed that quantum electrodynamics provides an exact description of all physical phenomena which do not directly involve nuclear forces, the weak interactions, or gravitation." * QED is used to explain the electrical and magnetic interactions of subatomic particles, and therefore goes to the heart of the nature of matter and energy. This theory has predicted, successfully, incredibly subtle events on an atomic scale at an accuracy that rivals the best measurements that modern science can make.

Because of this, according to the chief of the NBS Electrical Measurements and Standards Division, Dr. Barry Taylor, it is very important to constantly check the accuracy of QED, "especially in view of its somewhat controversial formalism and computational complexity." That is, the rather daring mathematical gymnastics and the awesome computational problems involved in QED—a single factor in a QED equation might itself be the result of literally hundreds of other calculations—make the theory extremely difficult to check at higher accuracies.

The redetermination of the gyromagnetic ratio of the proton was primarily the work of physicists Edwin Williams (top) and P. Thomas Olsen. Olsen holds a small self-propelled carriage which runs along the top of the solenoid coil and applies current to selected loops of wire in their measurement of the dimensions of the solenoid.

The Fine-Structure Constant

One of the most important physical constants in QED—in the sense that the speed of light or Planck's constant are important quantities—is the so-called fine-structure constant symbolized by the Greek letter α. In QED, α acts as a "coupling constant"—one of the physical quantities that appear in the equations that translate the theory to meaningful predictions about the real world. This means that the better we know α, the better we are able to test the accuracy of QED predictions.

Suppose, for example, we wish to find a value for the magnetic moment anomaly of the electron, a_e, which relates to the effect of a magnetic field on an electron. It is possible, using fairly sophisticated techniques, to experimentally measure a_e to within four parts in 10^8, a feat comparable to measuring the distance from Cincinnati, Ohio to Louisville, Kentucky (160 km or 100 miles) to within the width of a letter on this page. (This has been recently accomplished at the University of Washington by the team of H. G. Dehmelt, R. S. Van Dyck, Jr., and P. B. Schwinberg. Incidentally, a_e is the most precisely measured property of any elementary particle.)

In theory, one could also calculate a_e from the principles of QED and compare the two values. But since the equation which predicts a_e depends heavily on the value for the fine-structure constant, the comparison is no better than the experimental value for α. (There are other uncertainties in the calculated value of a_e based on the fact that only *part* of it can in fact be calculated at present. How-

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* *From* Principles of Modern Physics *by R. B. Leighton, McGraw Hill, 1959.*

ever, these less well known contributions are no more uncertain than α.)

Until the Williams and Olsen measurement, the best experimental value for the fine structure constant was good to a part in a million (1 in 10^6). Their most recent work has pushed that accuracy by a factor of 10 to 1 in 10^7, and they expect to be able to redo the experiment to within a few parts in 10^8 using more sensitive equipment now being built by NBS. This will bring the experimental value for α within range of the best experimental value for a_e.

One of the most important features of Olsen and Williams' new value of α is that it is independent of QED theory. Thus, it can serve as a check not only on the internal consistency of QED but on its accuracy in an absolute sense as well.

And the Gyromagnetic Ratio

To slightly complicate the issue, the fine-structure constant is not as a rule found by direct experiment, but, rather, calculated from an equation which gives α in terms of several other quantities: the speed of light; the Rydberg constant, which relates to permissible energy levels in an atom; the magnetic moment of the proton; the ratio of the charge of the electron to Planck's constant; and a quantity called the gyromagnetic ratio of the proton, written γ'_p (the ′ mark indicates that the value is for protons in water).

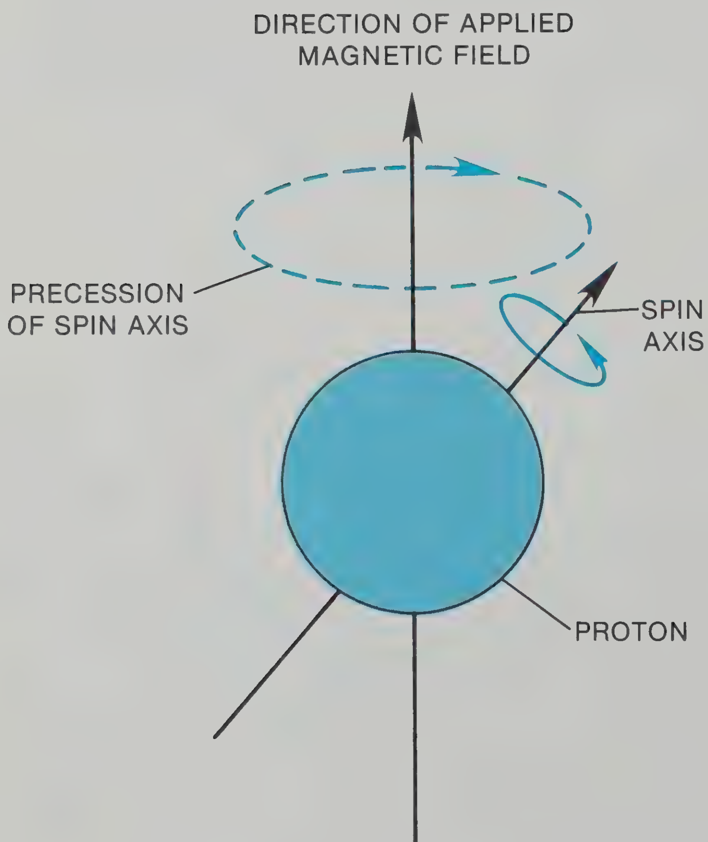
As it happens, all but the last value in this equation are already known to within one or two parts in 10^8 or better, so an improved value for the fine-structure constant depends essentially on improving the known value of the gyromagnetic ratio of the proton.

Which is? Well, a proton is a stable particle with a positive charge and a "spin." Most subatomic particles including protons are thought of as "spinning" about an "axis" like a child's top. This is not to say that they actually spin in any real sense of the word, since some of these particles have no mass to spin. But they behave *as if* they were spinning.

Like a spinning top, a proton will precess in the presence of a force field. In precession, the central axis of a top spinning under the force of gravity will slowly trace out a circle around the point of the top. A proton does the same thing in the presence of a magnetic field (or, rather, it *acts as if it did*). The stronger the field, the faster the precession, but the ratio of the rate of precession to the strength of the field is always constant, the gyromagnetic ratio.

The first really accurate measurement of the gyromagnetic ratio of the proton was made at the National Bureau of Standards in 1958 by Raymond Driscoll and Peter Bender. In a laboratory borrowed from the Coast and Geodetic Survey where there was special equipment to cancel the effects of the Earth's magnetic field, they measured the value of γ'_p to about a part in 10^5.

Since then, the gyromagnetic ratio has been used in the day to day work of monitoring the electrical standards for the nation. This was because γ'_p is a very convenient link between several different units: it is a constant which converts magnetic



In the presence of a magnetic field, a proton will precess. Thus, its spin axis will precess around the direction of the field in a manner similar to the wobbling of a top. The stronger the field, the faster will be the precession, but the ratio of the rate of precession to the strength of the field—the gyromagnetic ratio—is always constant.

field strength to frequency. For a given, unchanging coil of wire, the strength of the magnetic field inside the coil is directly proportional to the strength of the current going through the wire. You can monitor the stability and strength of the current by monitoring the stability and strength of the magnetic field, and you can monitor the magnetic field by monitoring (through γ'_p) the characteristic frequency of precession of a sample of protons inside the field. And frequency is one of the easiest things in all of physics to measure and monitor.

From 1958 to 1970, a chain of measurements such as this was used to monitor the stability of the official U.S. volt as maintained by NBS. The gyromagnetic ratio of the proton, as determined in the original experiment, was used almost weekly in this program, because although the *accuracy* of the measurement was pushed only to about a part in 10^6, the *precision* of the experiment—that is, the ability to get the same number every time—was about 10 times better, a part in 10^7. And for monitoring the *stability* of a quantity, precision is more important than accuracy. (By 1971, this method for monitoring the volt had been rendered obsolete by a technique using supercold electronic circuits and the Josephson effect.)

The Williams and Olsen Measurement

While γ'_p was losing its importance in the field of daily metrology, it was, for reasons noted above, becoming important in theoretical physics. By the early seventies, it was obvious that a new and better value for γ'_p, preferably accurate to a part in 10^8 or better, was going to be very necessary.

Unfortunately, the accuracy of the measuring techniques for this experiment, developed by Driscoll, Olson, and others, had been pushed about as far as they could be.

The basic strategy for measuring the gyromag-

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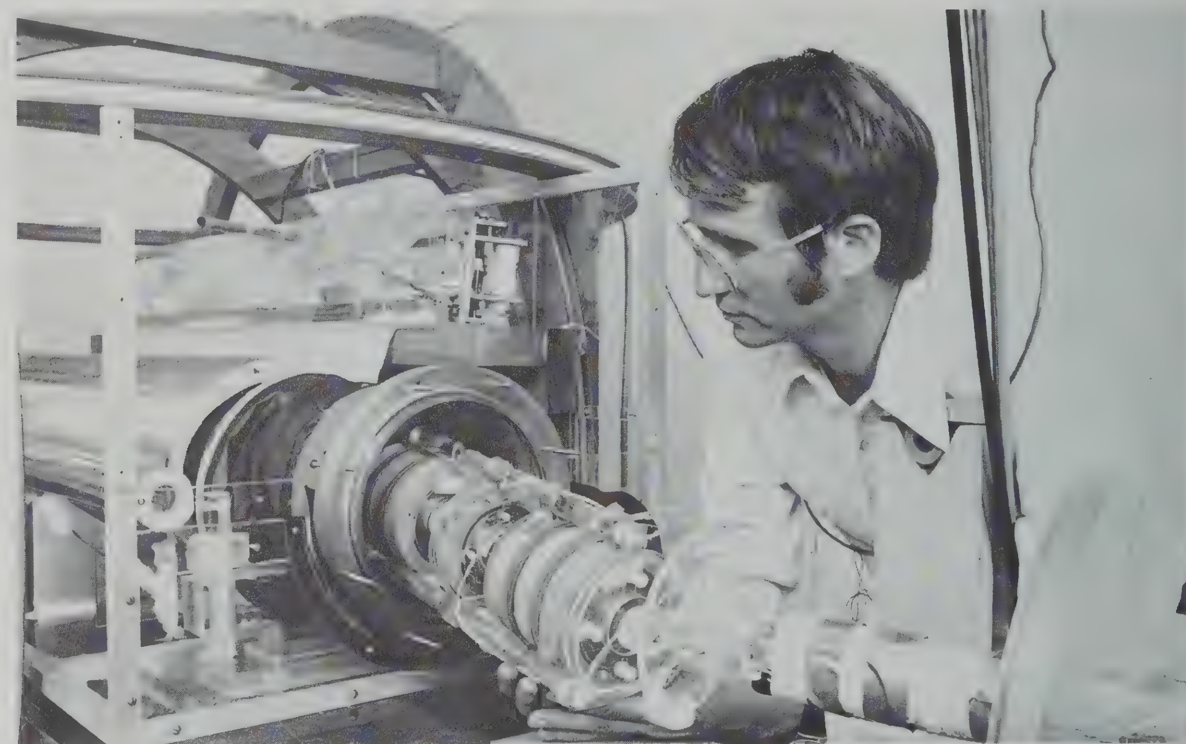
Physicists Raymond Driscoll (left) and Peter Bender with the equipment used to make the first accurate measurement of the gyromagnetic ratio of the proton at the Coast and Geodetic Survey lab in Fredericksburg, VA, 1958.

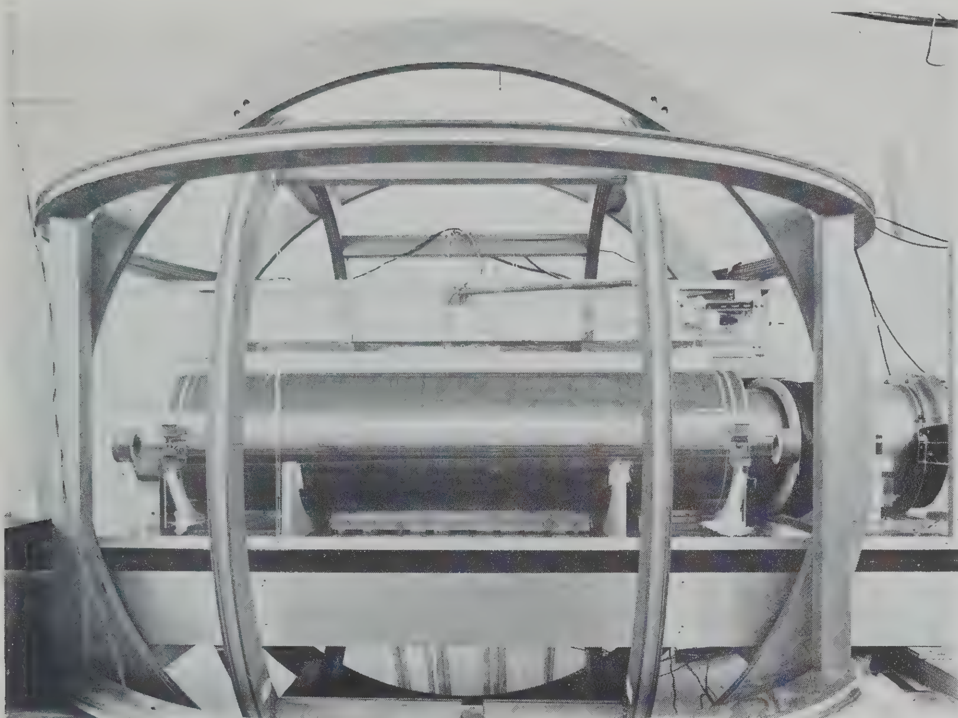
The purified water sample used in the gyromagnetic ratio experiment is encapsuled in a glass bulb. During the experiment, it rests in the center of the glass cradle below it, which is placed inside the solenoid. The small coil of wire which surrounds the bulb in the cradle is part of the apparatus used to detect the nuclear magnetic resonance phenomenon in the water sample.

netic ratio is to place a sample of protons—generally a small sample of water is used (the other atomic particles in the water don't interfere in the experiment)—in the middle of a very well-known magnetic field. The sample is bombarded with radio waves, and, by a phenomenon known as "nuclear magnetic resonance," the sample will absorb energy from the radio waves at the particular frequency that corresponds to the precession frequency of the protons. Sensitive instruments detect this effect, and it is a comparatively simple task to measure the frequency to very high degrees of accuracy. (In point of fact, scientists can measure frequency more accurately than anything else in the world: in the best of circumstances, to a part in 10^{13}.)

The hard part, therefore, is getting a "very well-known magnetic field." In the first place, the effects of the earth's natural but somewhat erratic magnetic field have to be nullified. Currently, NBS has one of the best facilities in the country for such work—a special building in a remote part of the grounds, constructed mostly of wood and concrete and designed to use no steel and no more nonferrous metal than absolutely necessary. In a second-floor room, large coils of wire ("Helmholtz



Williams loads a magnetic pickup probe into the solenoid. The probe is used to measure the pitch (number of loops per unit distance) of the coil that forms the solenoid. The two pickup coils used in the probe are at opposite ends of the assembly that Williams is holding. The beam of the laser interferometer runs through the center of the tube to a reflector mounted between the pickup coils.



To measure the gyromagnetic ratio of the proton, Williams and Olsen used this apparatus in the NBS Nonmagnetic Laboratory. The large plywood rings hold the "Helmholtz coils" which are used to counteract the Earth's magnetic field. The long coil or solenoid in the center produces the magnetic field used in the experiment.

coils") are used to counterbalance the earth's field and create a neutral zone in the center of the room.

The magnetic field for the experiment is provided by a large coil of wire, called a solenoid, which produces a magnetic field in the center of the coil when a current runs through the wire. The solenoid used in the most recent γ'_p measurement was about a meter long and 28 centimeters in diameter.

Now, given a coil of known physical dimensions with a known current running through it, it is comparatively easy to calculate the strength of the magnetic field in the center of the coil. The catch is that to obtain measurements with an accuracy of a part in 10^7, the dimensions and current have to be known very accurately.

Fortunately, accurately measured electrical currents are fairly easy to obtain at NBS, which maintains the official standards for voltage, current and resistance for the U.S. Williams, Olsen, and their colleagues designed and installed triply-shielded cable to carry a precisely monitored electrical current the 1500 meters from the electrical standards laboratory to the non-magnetic building. They found it possible to deliver a current to their solenoid accurate to within a few parts in 10^8.

A somewhat more serious problem, as it turns out, is the measurement that would seem to be the easiest: the physical dimensions of the coil. The strength of the magnetic field in the center of the coil also depends on the number of loops of wire per unit length.

Measuring the length of a coil of 1000 loops of wire would seem simple enough, but, in fact, this was the point where the old experiment reached its limits. The approach, used at NBS in the early seventies and still current in most labs around the world, was to very carefully locate physically the position of each loop in the coil, and, using a laser interferometer, to measure the relative spacing of each loop. (Wonderfully accurate devices, laser interferometers measure distances by counting the number of wavelengths of light crossed by a moving mirror traveling from one end of a course to another.) The process would then be repeated at intervals around the coil to measure variations in the coil.

However, when you are working with accuracies of one part in 10^7, measurements become quite tricky. The problem with the moving mirror system was that, although the current-carrying wire was less than one millimeter (0.04 in.) thick, there was no way to tell where *within the wire* the current would be flowing. Distortions in the shape of the wire, and impurities and stresses in the metal would all contribute to the path of the current.

The solution, advanced by Williams and Olsen in 1972 and eventually refined, was to ignore the wires entirely and measure the position of the current instead.

They reasoned that if a single loop of wire had an alternating current running through it, it would induce a similar current in any coil near it. Now if you had two small coils, essentially identical but wrapped in opposite directions, and positioned one on either side of the single loop, there would be

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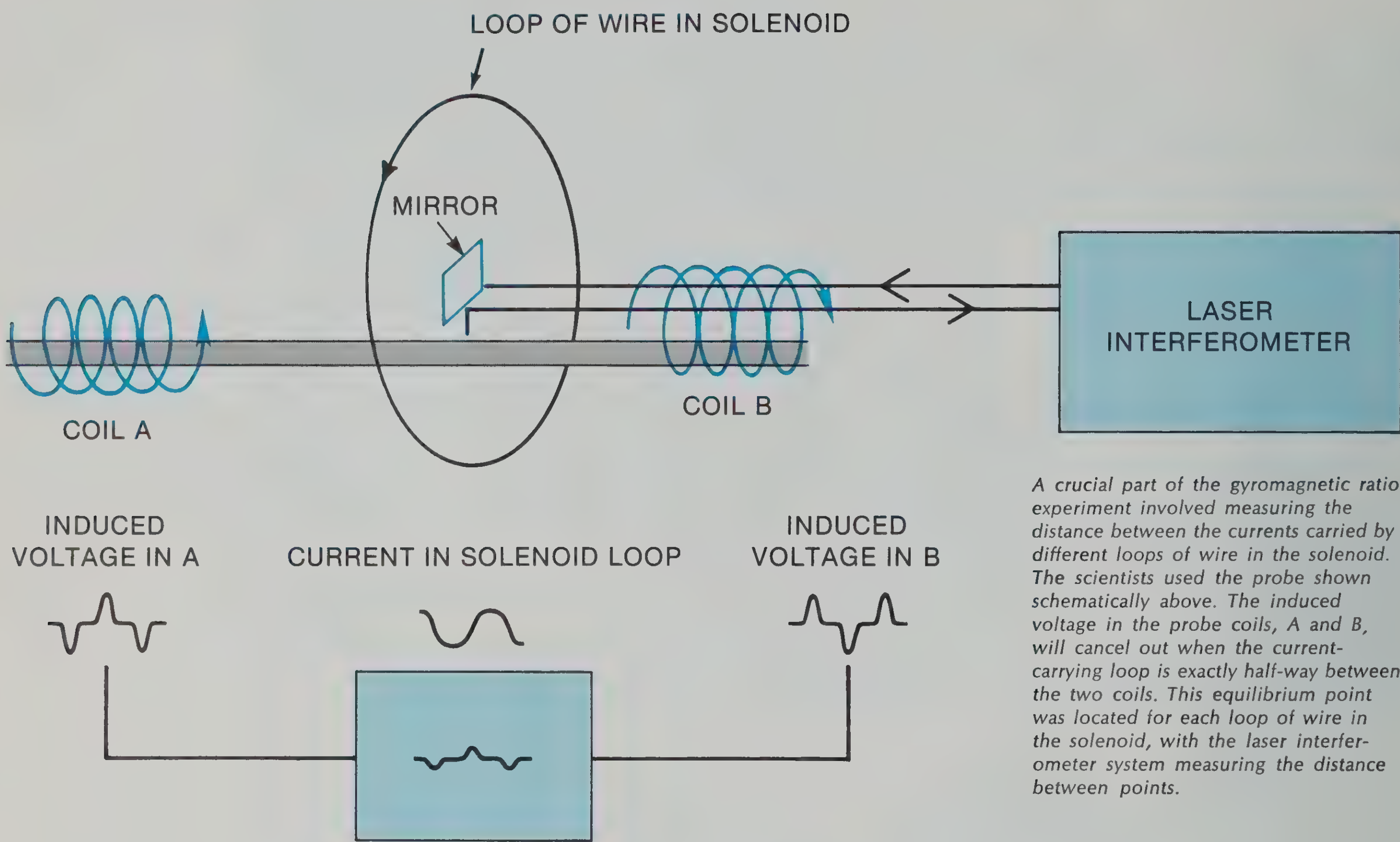


A crucial part of the gyromagnetic ratio experiment involved measuring the distance between the currents carried by different loops of wire in the solenoid. The scientists used the probe shown schematically above. The induced voltage in the probe coils, A and B, will cancel out when the current-carrying loop is exactly half-way between the two coils. This equilibrium point was located for each loop of wire in the solenoid, with the laser interferometer system measuring the distance between points.

one particular arrangement where the induced current in the first coil would just cancel the induced current in the second coil, which would be easy enough to measure, and at *that* point, the current in the loop of wire would be exactly half-way between the two coils. The scientists did this for all one thousand loops of wire (measuring ten loops at a time), and, with the aid of the laser interferometer, solved the length measurement problem.

For an infinitely long coil, these are the principal factors required to calculate the magnetic field. Since this coil has a finite length, the diameter of the coil also plays a part, so an adaptation of this method was used to measure the variations of the diameters of the loops as well.

Measuring the diameter of the coil proved to involve much the same problems, though an error in the measurement of the coil diameter affects the final figure less than an error in length. Williams and Olsen eventually solved this problem with a system of no fewer than five currents running through different parts of the coil at the same time in a pattern worked out by computer to produce a magnetic field as independent of the coil diameter as possible.

And Finally, The Results

Although the progress of the experiment seems very straightforward and smooth when summarized in this fashion, like most delicate experiments it involved long periods of painstaking construction of equipment and the even more painstaking search for "bugs" in the set-up.

The clever method for locating the position of a current in a loop of wire, for example, turned out to be subject to errors caused by the use of alternating currents (when the actual experiment is run, the coil carries a direct current). This was eventually solved, at the suggestion of Driscoll, through the use of a specially filtered alternating current in a method used at NBS before World War II.

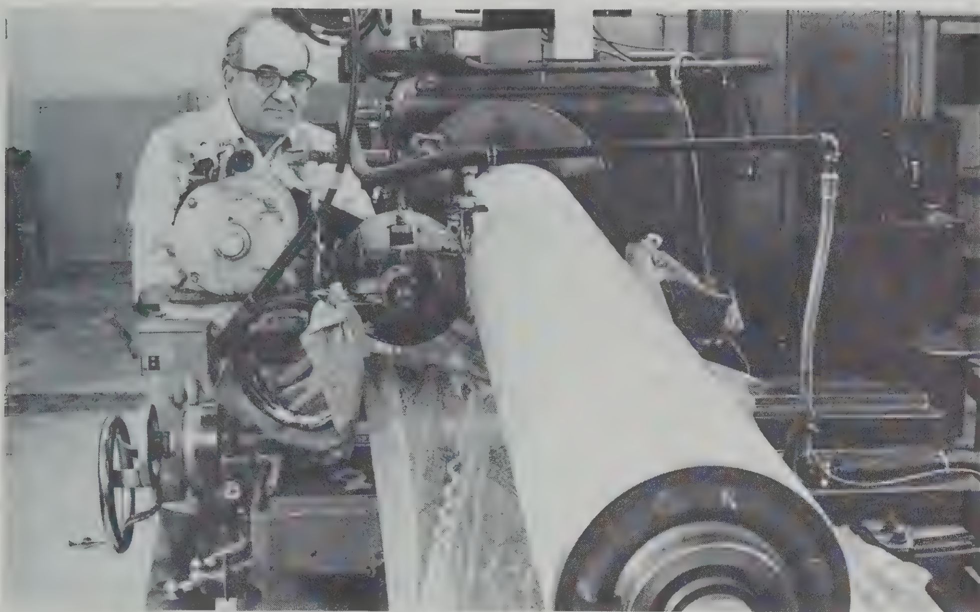
Even more vexing, the length of the coil seemed to change—to shrink—with successive measurements, a phenomenon that would disappear when people returned from vacations or conferences. This was eventually traced to minor short circuits caused by leaking batteries (which were customarily replaced when people returned from vacations or conferences.)

At length, however, the details were worked out and the measurements made. For the record, the measured value is:

$\gamma'_p(\mathrm{low})_{\mathrm{NBS}} = 2.675\,132\,29 \times 10^8\ \mathrm{s}^{-1}\mathrm{T}_{\mathrm{NBS}}^{-1}$ with an uncertainty of 0.21 ppm. From this we calculate:

$\alpha^{-1} = 137.035\,963$ with an uncertainty of 0.11 ppm.

As a matter of note, this value for the gyromagnetic ratio of the proton is different from the



The next generation of apparatus for the gyromagnetic ratio experiment is under construction in the NBS shops. Instrument maker Michael Mucci watches a precision lathe grind the quartz cylinder of a new solenoid down to an approximation of roundness. Before finishing, the cylinder will be lapped in an optical shop and engraved with a spiral groove to hold the solenoid wire—all to a tolerance of less than one millionth of a meter.

value generally found in other laboratories around the world, or, as Olsen says, "Everybody else in the world disagrees with us about 6 parts per million."

(Although this difference is large compared with the 0.2 ppm uncertainty of this NBS work, it is not large compared to the 4 to 6 ppm uncertainty claimed by the other laboratories.)

The discrepancy is interesting, because the other laboratories that have attempted the measurement (at lower levels of accuracy) more or less agree among themselves, and the NBS value has been consistently different by about 6 ppm over the years. The only thing that has changed is that the uncertainties in the NBS measurements have been reduced.

"Of course, in comparing experiments, any time there is a discrepancy, there is some cause for concern," says Williams, "but we've gotten enough consistency in our various redundant methods that we're not especially concerned if one considers the level of accuracy achieved elsewhere."

One of the things that has been achieved elsewhere, with high accuracy, is the previously mentioned measurement of a_e at the University of Washington, a measurement that fits much better with the NBS value for γ'_p than any other. But here too there is an interesting discrepancy. These two measurements serve as the most precise check on the consistency of QED ever made, and, curiously enough, they disagree. The best experimental value and the best QED-calculated value for a_e using the new NBS result for α differ by about 3 parts in 10^7.

Which leaves everyone where? Well, the current mood is closer to curiosity than panic. As Taylor notes, the theoretical QED calculations, by virtue of their complexity, are sufficiently incomplete that a discrepancy so close to the limits of experimental accuracy is not yet serious.

The next step will be to refine the two complementary measurements and the theoretical calculations. Dehmelt's group at the University of Washington expects to be able to improve their measurement to within a single part in 10^8 or better in the next few years. The theoreticians are plugging away with their computers to refine their calculations so that the theoretical uncertainty in a_e will also be of about the same amount, and the NBS team is in the process of building a new solenoid to repeat their experiment at a similar level of accuracy. The new solenoid will be more than twice as long as the old one, reducing the error caused by the solenoid diameter measurement.

The exciting possibility that a true discrepancy can be "discovered" is one reason why all of these workers are pressing ahead with this difficult research. Is QED exactly right? At what level of accuracy does it break down? We will have to wait at least several years to find out the answer. □

Fire Safety Tips for Wood Burning Appliances

PROPER INSTALLATION, OPERATION AND MAINTENANCE

by Susan Lieberman

One cold winter night you are getting ready to have company and decide to light a fire in the wood-burning stove. Your company arrives. Everyone is luxuriating around the stove when the room begins to get uncomfortably hot, and you hear strange noises coming from the chimney. As you glance toward the chimney, you notice a reflection of your house in your neighbor's window. Flames and smoke are billowing out of your chimney and sparks are landing on the roof.

Wood-burning stoves and fireplaces are gaining popularity as alternative energy sources in residences, but unless they are used carefully, they can cause disastrous fires. In February 1978, the Center for Fire Research at the National Bureau of Standards undertook a project sponsored by the

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As Americans seek alternative sources of heat, stores that sell wood-burning stoves—such as this one of yesteryear—are enjoying increasing popularity.

Department of Energy to investigate the fire safety of wood-burning appliances.

A wood-burning appliance is either a factory-built heater or fireplace, such as the pot-belly and Franklin stoves, or a custom-built fireplace. The appliance always consists of a fire box and chimney. When the firebox is not built directly below the chimney, a stovepipe (also called a chimney connector) will connect the stove and chimney.

Wood-burning appliances can be safe if you follow some simple guidelines. NBS has examined fire incidents associated with these stoves and fireplaces and found that most of the dangers come from improper installation, operation, and maintenance rather than from the design and construction of the stove itself.

The following fire safety tips are given to help you avoid an unwanted fire. Some tips may appear obvious but they are often the ones that are overlooked. This list is not definitive; as research by NBS and other groups continues, further information on the safe use of wood as fuel will become available.

There are seven problems with the installation and use of this stove that could lead to a house fire. How many can you identify? Answers can be found at bottom of page 22.

Installation

Most new stoves are made of cast iron or steel. Buy one that has been certified by a recognized testing organization (for example, Underwriters Laboratories). If you buy an antique stove, examine it carefully for cracked, missing, or malfunctioning parts.

—Many stoves come with installation instructions. Follow them closely. Be wary of buying a new stove without complete installation instructions.

—A stove should be installed at least 90 cm (36 inches) from the ceiling and walls, unless the walls are protected with mineral wool paddings covered by sheet metal spaced 2.5 cm (1 inch) from the wall. In this case, a 45-cm (18-inch) clearance is recommended.

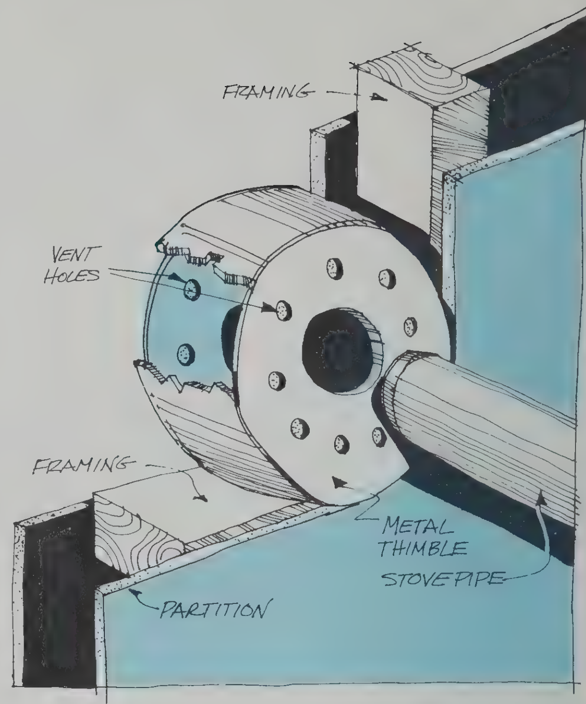
—The stove should not be mounted on an unprotected combustible floor. Unlike walls and ceilings which need to be protected only from radiant heat, floors need to be protected from glowing embers which may fall from the stove. For this reason, a stove should be mounted on an approved stove mat such as fiberglass batts covered with sheetmetal, mortared bricks, stone, or concrete with at least 10 cm (4 inches) of clearance from the stove to the floor. The floor protection should extend at least 45 cm (18 inches) in front of the stove so that embers removed with the ashes do not fall on an unprotected floor.

—A stove should be installed at least 90 cm (36 inches) away from furniture, drapes, and carpets. If you put your hand on the furniture and it feels hot, it is probably too close to the stove. Also make sure that drapes won't blow too close to the fireplace or stove.

—The stovepipe may connect directly to an existing masonry chimney or through a wall to the chimney. Single wall stovepipes must not pass through the ceiling and should be at least 45 cm (18 inches) from the wall and ceiling joint. There are several ways to prevent fire in the wall if a single walled stovepipe passes through the wall. The wall should be protected either by a ventilated thimble (a round piece of metal that fits around the pipe) with a diameter 30 cm (12 inches) greater than pipe, or by an unventilated thimble. (With this type of thimble, fireproof materials must also ex-

turn page

A ventilated thimble permits a stovepipe to pass safely through a combustible wall.



tend at least 22.5 cm (9 inches) beyond the thimble on all sides of the pipe.) If no thimble is used, the hole should be covered by at least 45 cm (18 inches) of non-combustible material on all sides of the pipe. With a stovepipe 15 cm (6 inches) in diameter, this would require a 105 cm (42 inch) diameter hole through a combustible wall.

—To allow installation without such large clearances, specially constructed double-and triple-walled insulated chimney connectors are available. Double-walled stovepipes are two concentric metal pipes separated by an insulating material or an air pocket which acts as insulation. Triple-walled ones utilize the same principle with 3 concentric pipes. Follow installation instructions with these closely.

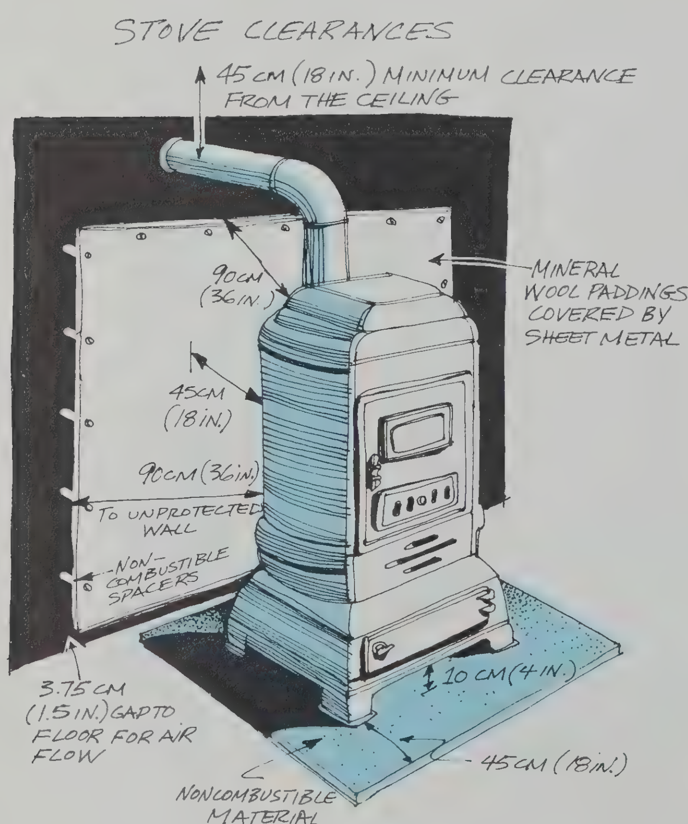
—Contact your local building code officials for a building permit before installing a chimney. After the chimney is installed have the building official check it.

—Masonry chimneys should be at least 10 cm (4 inches) thick; 30 cm (12 inches) if they're made of rubble stone masonry. They should have at least 1.5 cm (⅝ inch) fire clay flue lining. Factory-built chimneys should be approved by various standards organizations and should conform to building codes. These factory-built units should be installed according to the manufacturer's directions.

—Chimneys must extend at least 90 cm (3 feet) above the highest point where they pass through the roof and at least 60 cm (2 feet) higher than any portion of the building within 300 cm (10 feet).

—If you have more than one appliance, wood-burning or otherwise, being vented through a single masonry chimney, each passageway should be separated by at least 10 cm (4 inches) of masonry bonded into the wall of the chimney.

—Install a spark screen over the outside opening of your chimney. This prevents sparks from escaping and causing roof or exterior building fires.



Operation

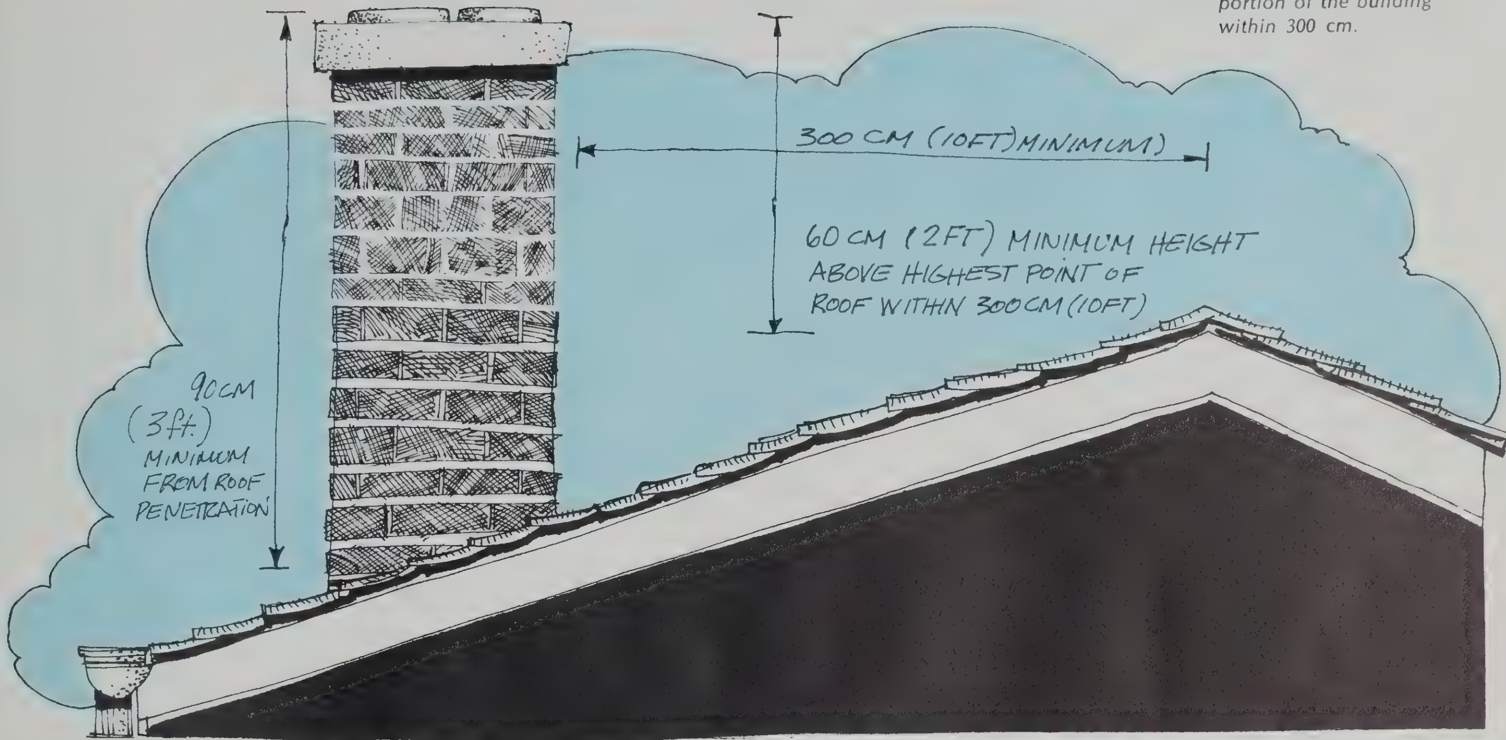
A correctly installed wood-burning stove or fireplace can still pose a fire hazard if it is not used properly.

—Remember not to place any combustibles near the stove; in addition to furniture, throw rugs, or pillows, this includes newspapers which you might use to start a fire. A hot ember could fall from the stove or fireplace and start a fire.

—Never use flammable liquids such as kerosene or gasoline to start or rekindle a fire. These materials can cause explosions.

—Don't touch a stove to see if it's hot!

A chimney must extend at least 90 cm above the highest point where it passes through the roof and at least 60 cm higher than any portion of the building within 300 cm.



—When wood-burning appliances are in use, children must be closely supervised. Unaware of the potential dangers of wood-burning stoves, children may touch one and be burned, or may accidentally bump into the stove and tip it over.

—Another cause of serious accidents is ignition of clothing. Make sure that you do not wear loose or flowing garments when adding wood to the stove or fireplace. Also, be careful that hot embers do not fall onto your clothing.

—Do not use coal in a wood stove and vice-versa unless the manufacturer has indicated that it can handle both fuels.

—Don't overload the fireplace with wood or use damp or green wood.

—Don't use the appliance for trash disposal.

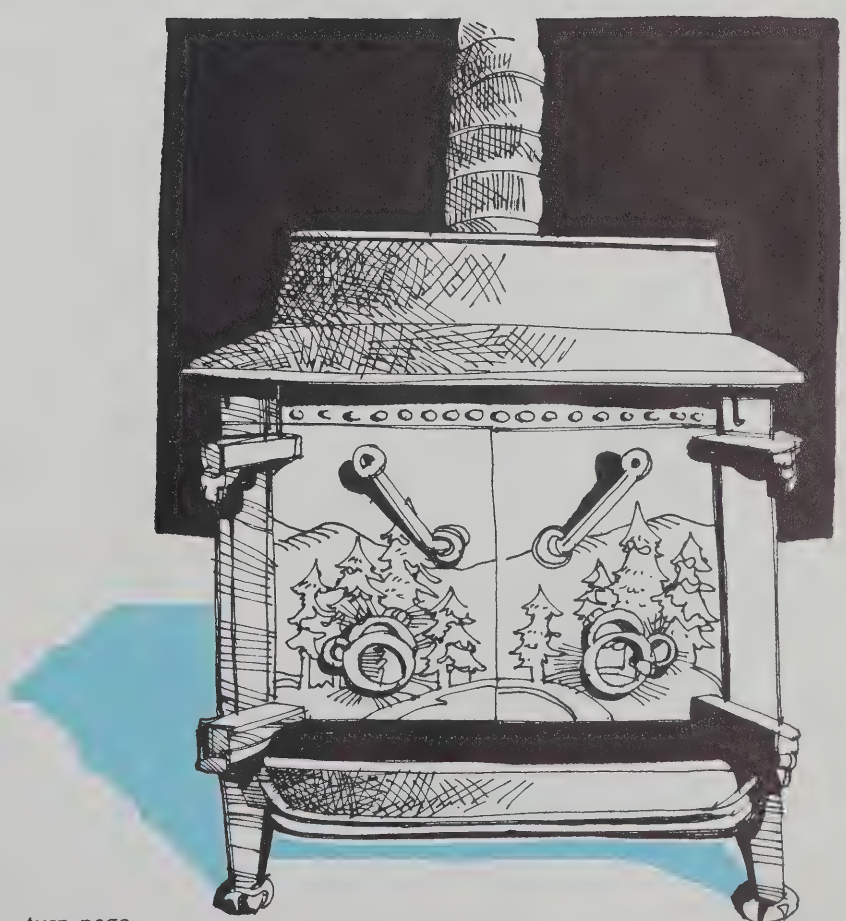
—Open a window to allow fresh air into the room when you use the stove for long periods of time.

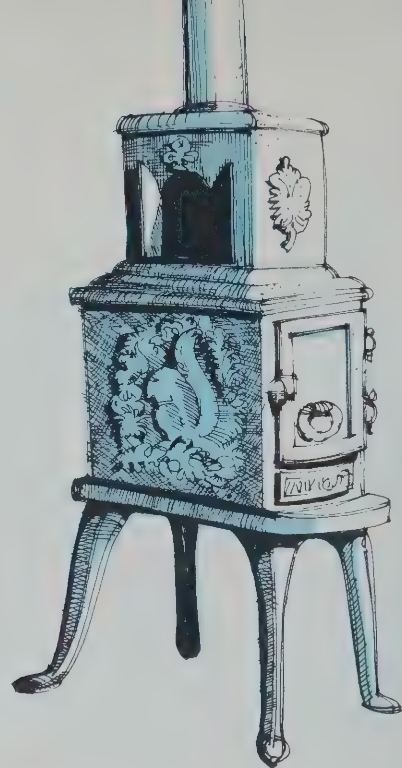
—Use metal containers to remove ashes. And *do* remove them.

—Don't use artificial logs in a wood-burning stove. They can create a fire that is too hot which, in turn, can cause chimney fires and structural damage to the stove. Artificial logs contain a lot of wax which can either clog up the air inlet in factory-built stoves or run out of the stove. The air inlet is needed for proper ventilation and, sometimes, cooling the walls.

Maintenance

You've installed your wood-burning system *turn page*





properly. You are careful not to create any fire hazard when you use the stove or fireplace. But if you don't clean the system and periodically check to make sure that all the components are operating properly, you could still have a fire.

—One danger with any kind of wood- or coal-burning system is creosote build-up on the inside of the chimney. Creosote, a very flammable by-product of wood combustion, can cause very hot chimney fires.

When you first begin using your wood-burning system, you should inspect your chimney regularly at least at two week intervals for creosote. When you see how fast creosote accumulates you can determine how frequently you should inspect and clean your chimney. You can hire professional chimney cleaners or do it yourself. The chimney should also be checked periodically for structural damage.

—Creosote can also eat through chimney connectors. Check the stovepipe regularly to make sure that its components have not corroded and are connected tightly.

—If your stove has a thermostat, make sure it is working properly.

If you should have a chimney fire: close the damper to cut off the air supply to the fire. Evacuate the house. Call the fire department from a neighbor's. Wet down your roof and other outside surfaces to prevent fires from sparks.

Before using the system again, check the stove, chimney connector, and chimney thoroughly to be sure that the fire hasn't weakened any part of the system from the intense heat.

Insuring Safety

Once your wood-burning system is installed, you should call your local fire department or fire marshal and ask them to send someone to your house to inspect the system. They can certify that your system has been installed properly and safely.

Notify your insurance company that you have made this addition to your house. If you don't and you have a fire, your policy might be invalid.

One last safety tip—install a smoke detector on each story of the house, particularly outside bedrooms. Residential fires are especially disastrous at night. A smoke detector can awaken and warn you of a fire while there is still time to get out of the house and call the fire department.

Wood-burning stoves can be a safe and effective alternative or supplement to other types of heating. Fireplaces can provide a relaxing atmosphere. Both require work so that the pleasure they provide won't turn into disaster. □

The safety hazards in the photo on p. 19 are:

- the wall around the stovepipe is not protected with a thimble or noncombustible material;
- the combustible floor is not protected;
- the stove is too close to an unprotected wall;
- a combustible cardboard box containing wood is too close to the stove;
- a combustible carpet is too close to the stove;
- there is no spark screen;
- unless the manufacturer specifies that both wood and coal may be burned in the stove, only one should be used.

TENTH ANNIVERSARY OF NBS-TAPPI COLLABORATIVE REFERENCE PROGRAM FOR PAPER

by Theodore W. Lashof

In 1969, the National Bureau of Standards and the Technical Association of the Pulp and Paper Industry (TAPPI) established the first of a series of NBS collaborative reference programs (CRP) to help testing laboratories evaluate and improve the accuracy and precision of their procedures. In addition to paper, items now included in the programs are container-board, rubber, forensic materials, and most recently, thermal insulation.

During its first 10 years, the NBS-TAPPI CRP dealt primarily with analyses of physical and optical properties of quality printing and packaging papers, such as strength, gloss, and opacity. The program is now being expanded to include tests of additional characteristics of these papers as well as of the more important properties of newsprint, catalog, and directory papers.

Laboratories voluntarily subscribe to the program and select the tests in which they wish to participate. Periodically, the Bureau prepares two different samples of paper for each test and sends them to participating laboratories where the samples are tested in accordance with TAPPI methods and instructions provided by NBS. The laboratories' values are then forwarded to NBS where they are statistically evaluated, using Youden's two sample analysis*. These results are then presented graphically and in tables so that each laboratory can readily determine the level and uniformity of its test values in comparison with those of other participants.

Also provided are best values, which are estimates based on careful examination of all available data, both current and past, with special attention to values obtained by NBS and other recognized U.S. and foreign reference laboratories.

Over the years, the TAPPI program has grown from approximately 100 participants and nine test methods to 260 participants and 25 test methods. Subscribers include both domestic and foreign paper mill and research laboratories as well as consumer, government, and commercial testing laboratories. For further information concerning NBS collaborative reference programs, contact Shirley Baile, National Bureau of Standards, Technology Building, Room A05, Washington, D.C. 20234, 301/921-2946.

Dr. Lashof is a research associate in the NBS Office of Testing Laboratory Evaluation Technology.

* *J. Mandel and T. W. Lashof, Interpretation and Generalization of Youden's Two-Sample Diagram, J. Quality Technology 6 (1), 22-36 (Jan. 1974).*

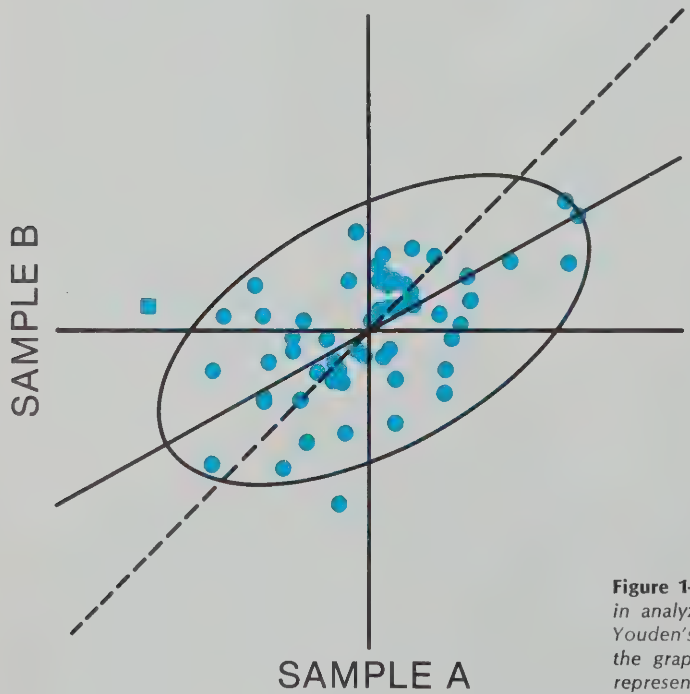


Figure 1—*One of the statistical methods used in analyzing the results of laboratories' tests is Youden's two sample analysis. Each point on the graph represents a laboratory; the ellipse represents the bounds within which 95 percent of the points for similar laboratories should fall. From this diagram, each participant can determine how well its testing values compare with those of other laboratories in the CRP.*

NBS ANNOUNCES FOUR COMPUTER INTERFACE STANDARDS

by Shirley Radack

A new Federal computer standard for connecting magnetic disk peripheral equipment as a part of large and medium scale computer systems was announced by NBS in August 1979. This standard is the fourth in a series of input/output (I/O) channel level interface standards that are expected to save the Federal Government $61 million over the next five years through competitive procurement of computer peripheral equipment.

The four Federal I/O interface standards, all issued in 1979, are:

—Federal Information Processing Standard Publication (FIPS PUB) 60, *I/O Channel Level Interface* which defines the mechanical, electrical, and basic functional specifications of the channel level interface.

—Federal Information Processing Standard Publication (FIPS PUB) 61, *Channel Level Power Control Interface* which defines the functional, electrical, and mechanical interface for use in connecting computer peripheral equipment as part of ADP systems.

—Federal Information Processing Standard Publication (FIPS PUB) 62, *Operational Specifications for Magnetic Tape Subsystems* which defines the use of the channel level interface for connection of magnetic tape peripheral equipment.

—Federal Information Processing Standard Publication (FIPS PUB) 63, *Operational Specifications for Rotating Mass Storage Subsystems* which defines the use of the channel level interface for connection of magnetic disk peripheral equipment.

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FIPS 60, 61, and 63 provide the full channel level interface specifications for magnetic disk and other similar equipment. The full channel level specifications for magnetic tape peripheral equipment are provided by FIPS 60, 61 and 62.

These standards are for use by Federal agencies in all procurement solicitations and orders for medium and large scale computer systems and peripheral devices to be connected as part of these systems unless a waiver has been obtained from the Secretary of Commerce. The effective date for FIPS 60, 61, and 62 in solicitations and orders of equipment interfacing magnetic tape equipment is December 13, 1979. The effective date of FIPS 63, and of FIPS 60 and 61 when used for Federal orders and solicitations of computer equipment interfacing magnetic disk equipment is June 23, 1980.

Small computer systems costing less than $400 000 in their "maximum normally employed configuration" have been excluded from compliance with Federal interface standards. Information about the exclusion list is available from Director, ICST, Attention: Interface Standards Exclusion List, National Bureau of Standards, Washington, D.C. 20234.

Guidance to Federal managers in planning, acquiring and operating ADP systems that involve products and services obtained from multiple sources was issued last year. FIPS PUB 56, *Guidelines for Managing Multivendor Plug-Compatible ADP Systems,* identifies problems that are encountered in managing multivendor systems and provides guidance for avoiding and solving them.

FIPS PUBS 56, 60, 61, 62, and 63 are available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, Virginia 22161. Telephone: 703/557-4650.

The large and medium scale computer systems for which these Federal computer standards are applicable generally have two areas of linkage or interface between the central processing units and the peripheral devices:

- the *channel interface* between the input/output channel of the central processing unit and control units;
- the *device interface* between the control units and the input/output devices such as tape and disk units.

Additional standards applicable to both interface areas are slated for development under the Institute for Computer Sciences and Technology's program in computer systems and network interface standards. As with the standards already issued, the government is expected to benefit from reduced costs of peripheral equipment through more competitive procurement and assurance of reliable and efficient operation of equipment and components.

Scheduled for development through the mid-1980's are: line printer operational specifications to define the channel level interface for connection of printing equipment; magnetic disk device and magnetic tape device interface standards to provide plug-to-plug interchangeability for magnetic tapes and disk drives. Also scheduled for development are interface standards for connecting equipment and components as part of mini-and microcomputer systems. Aided by two Research Associates working with ICST staff under government/industry cooperative agreements, investigation has begun on developing the technological foundation for additional forward-looking interface standards planned for the mid-1980's.

STAFF REPORTS

NEW PHOTOMETRIC CALIBRATOR PERFORMS DIRECT MEASUREMENT

A new "Inverse Fourth Power Photometric Calibrator," invented and built at NBS, can perform direct, rather than comparison, measurements of optical transmittance and density over a range of nearly six orders of magnitude. The device accomplishes measurements over this wide breadth without "bootstrapping," that is, without using the sum of many smaller measurements to extend its measuring range. The Inverse Fourth Power Photometric Calibrator was developed to extend the range and increase the accuracy of NBS photographic-type optical density standards. These film standards have varied applications, from the control of manufacturing processes of photographic film and paper to the x-ray nondestructive testing of aircraft and nuclear reactor components.

Dennis A. Swyt and Russell D. Young, Mechanical Processes Division, A123 Metrology Building, 301/921-2159, and James G. LaRock, Instrument Shops Division, 139 Shops Building, 301/921-2158.

A variety of industries need calibrated transmission density standards with accuracies of about 0.5 percent (in density) over a range of 0.05 to 6.00 density units, corresponding to 0.000 001 00 ± 0.000 000 07 transmittance units. A primary calibration of such standards requires a direct measurement, one not involving a comparison to another calibrated standard of the same kind. A few devices have this direct-measurement capability, but none has been reported to be capable of measuring these extremely low transmittances (i.e., high densities) without some type of bootstrapping which is subject to accumulating errors. The Inverse Fourth Power Photometric Calibrator shown in figure 1 was developed to overcome this limitation. The principle of the device is a variation of a phenomenon encountered in radar tracking of satellites and flash photography—the strength of a signal which is returned to its source after being reflected by a target will depend on the inverse fourth power of the distance between the source and the detector.

In this new device, the "target" is a flexible light guide, consisting of a bundle of optical fibers, which collects light from the primary point source, "turns it around" and re-emits a fixed fraction as a secondary point source back toward the source-detector plane (figure 2). Between the source and detector is a folded optical path consisting of two parallel, optically-isolated enclosures which form separate paths (a) between the source and one end of the light guide and (b) between the other end of the guide and the detector. The light guide is mounted on a stepmotor-driven carriage. It can be moved over a distance of 3000 mm with its position measured to 0.01 mm. The complete system is shown schematically in figure 3.

Figure 1—*The inverse fourth apparatus for photometric calibrations with enclosure covers removed to show movable baffles with drive tapes. The baffles are black, although they appear lighter.*

Measurement of a filter's transmittance depends on the following relationships: 1) the output, i, of the detector is proportional to the flux, F, it receives; 2) the flux the detector receives is proportional to the inverse fourth power of d, the effective distance between the source and the detector; and 3) a filter's transmittance, T, is the ratio of the flux, F_t, it transmits to the flux, F_o, incident upon it.

To carry out such a measurement the carriage is first stationed at some position, d_1, and the output of the detector, i, is noted. A filter is then inserted in the light path. The carriage is moved toward the detector to the position, d_2, where the detector output is reestablished. The transmittance, T, is then given by solving the two simultaneous equations, $i=k_1F_o=k_2/(d_1)^4$ and $i=k_1F_t=k_2T/(d_2)^4$ where $T=(d_2/d_1)^4$.

Repeated measurements made in this way over the 3000 mm distance traveled result in three-sigma standard deviations of less than 0.002 density units, a significant increase in precision over the in-

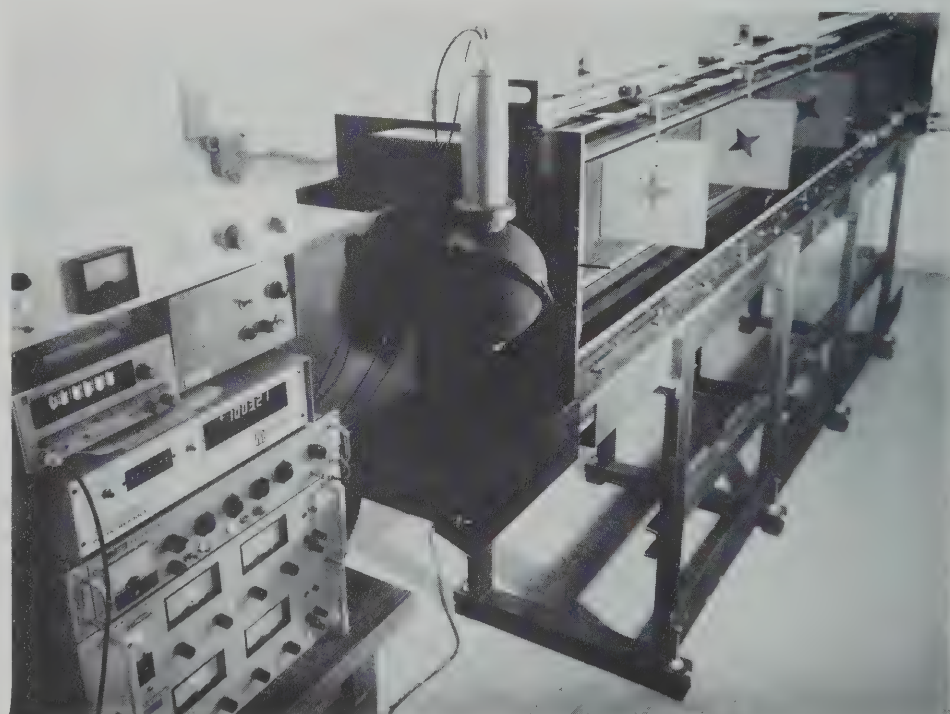
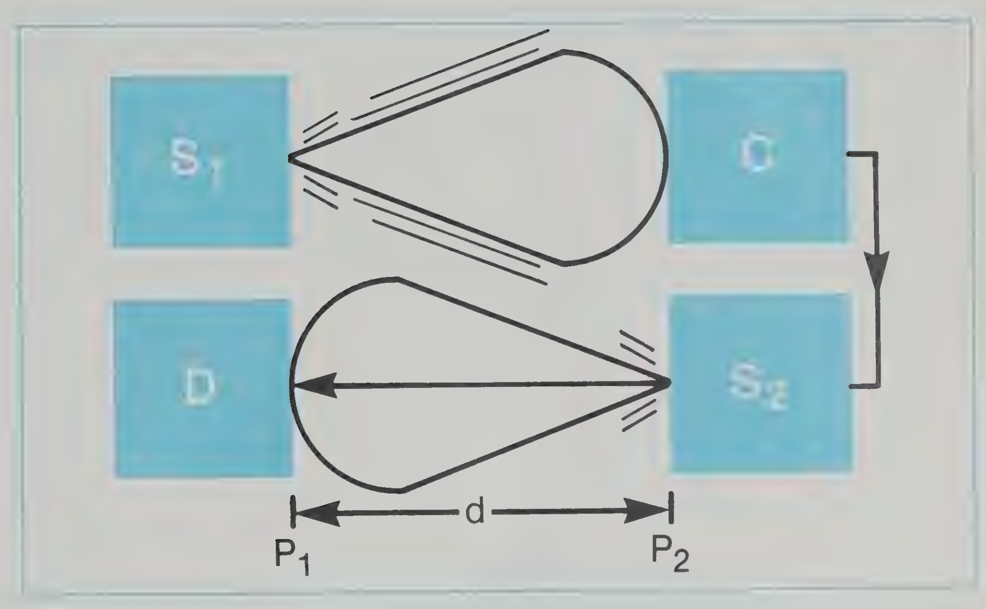


Figure 2—*The inverse fourth photometric calibrator. The apertures of the primary source S_1 and the detector D lie in plane P_1 separated by variable distance d from plane P_2 which contains the apertures of the collector C and the secondary source S_2.*



verse-square apparatus which this device is intended to replace.

In addition, the new apparatus allows measurements of much smaller transmittances. On the inverse-square apparatus with its 6-m length and 1-m closest approach, the minimum transmittance measurable without bootstrapping is 0.03 (or 1.5 density units). The inverse fourth system measures down to 0.000 001 5 (5.8 density units). To accomplish the same measurement, the old system would need to be an impractical 800 m long.

Patented by NBS under the names Swyt and Young*, with engineering design by James LaRock, the device is currently being used by researchers in the NBS Radiometric Physics Division for calibrating photographic film standards.

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* U.S. Patent 4152074, "Inverse Fourth Power Photometric Calibrator," May 1, 1979.

Figure 3—*Diagram of mechanical apparatus and electronic instrumentation of inverse fourth photometric calibrator showing the lamp power supply (LAMP PS), the photomultiplier power supply (PMT PS), the current-to-frequency converter (I-f CONV) with counter and display, as well as the step-motor control and position readout (DISPLAY d-POSITION).*

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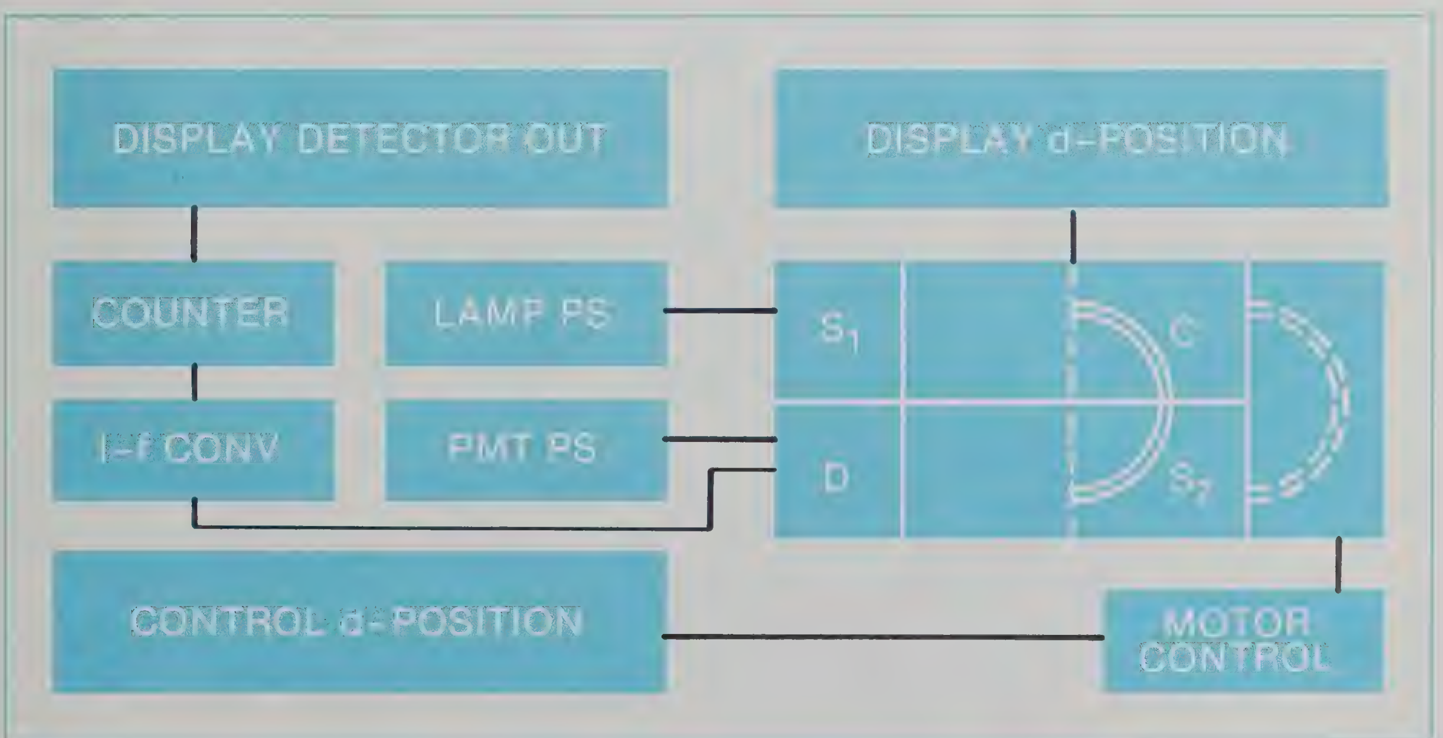


GIRTH WELD STANDARDS FOR ALASKAN NATURAL GAS PIPELINE

The Alaskan Natural Gas Transportation Act of 1976 and President Carter's Decision and Report to Congress on the Alaska Natural Gas Transportation System of 1977 provide for construction of a pipeline system to bring Alaskan natural gas to the lower 48 States. The Department of Transportation has requested assistance from the National Bureau of Standards to provide the technical framework for the formulation of guidelines and procedures for establishing flaw-size standards for girth welds in the Alaska portion of the transportation system. These standards would be used as a possible alternative to the present acceptance standards in the Federal gas pipeline safety regulations. NBS expertise is involved in the following areas: nondestructive ultrasonic and radiographic evaluation, mechanical properties, fracture mechanics, fatigue, and inspection of natural gas pipeline girth welds.

Richard P. Reed, Fracture and Deformation Division, Building 2-1228, Boulder, Colo., 80303, 303/499-1000, ext. 3870.

In 1976, NBS assisted the Materials Transportation Bureau (MTB) of the Department of Transportation in developing oil pipeline girth weld-quality assessment models based on fracture mechanics for the Trans-Alaska Pipeline. This was the first time in the United States that fracture mechanics had been used in the field to evaluate the significance of flaws in pipeline girth welds.

The current MTB request for NBS assistance relates to the construction of a natural gas pipeline system which will bring Alaskan natural gas to the lower 48 States. MTB is in need of guidelines and procedures for evaluating natural gas pipeline girth welds similar to the oil pipeline assessments previously provided by NBS.

NBS research will be used to provide a basis for (1) formulation of alternative allowable defect sizes, (2) recommended practical field inspection techniques and standards for the gas pipeline for flaw sizes in excess of the present weld quality standards, and (3) recommended practical procedures to implement techniques in the field. The information is to be coordinated with the gas pipeline companies before construction, and, therefore, to prevent delays or changes in procedures and eliminate unnecessary remedial welding. Also, the structural integrity of the pipeline material and welds is to be carefully documented to assure safety concerns associated with the pipeline.

The Alaskan portion of the natural gas pipeline consists of pipe 1200 km long with an outside diameter of 122 cm and a wall thickness of 1.5 cm. Present plans call for a maximum allowable pipeline operating pressure of 8.7 MPa.

Originating at Prudhoe Bay, the pipeline generally will parallel the Alaska oil pipeline, cross the Brooks Range through the Atigun Pass, and continue on to Delta Junction. At Delta Junction, the pipeline will diverge from the oil line and follow the Alaska Highway to the Alaska/Yukon Territory border.

The Canadian portion will proceed south, generally parallel to the Alaska Highway, and continue through British Columbia to Alberta where the transportation system splits. The western leg of the system will cross the border near Kingsgate, British Columbia, for ultimate distribution through Idaho, Washington, Oregon, and California. The eastern leg will cross the border near Monchy, Saskatchewan, and become the proposed Northern Border Pipeline System for transportation through Montana, North Dakota, South Dakota, Minnesota, Iowa, and to a final point south of Chicago.

Overland oil and natural gas transport pipelines are constructed of lengths of steel pipe welded end-to-end. Each pipe segment is pressure tested during manufacture. Upon completion of a pipeline, the system is hydrotested. These tests evaluate pipe quality and the integrity of the longitudinal seam welds. However, since the axial-direction stress level is at most half of the hoop-direction stress level, pressure tests do not adequately evaluate the girth welds that link the pipe segments. The safety of these joints depends on the quality of the girth welds. Weld quality is achieved by using properly prepared weld joints and qualified weld procedures and welders, and by inspection and testing of production welds. Weld inspection records are judged for quality by standards of acceptability established by the API-AGA (The American Petroleum Institute and the American Gas Association) Joint Committee on Oil and Gas Pipe Line Field Welding Practices and published as API Standard 1104.

Federal safety regulations stipulate that pipeline girth-weld acceptability be determined by the weld-quality requirements of API Standard 1104. For each characteristic type of flaw, allowable sizes are set forth in API 1104 as determined by considerations of workmanship. Flaw-size limits are based on quality levels reasonably expected from a qualified welder using satisfactory materials, equipment, and procedures. Pipe size, strength and toughness, weld properties, or pipeline operating conditions are not considered in these quality requirements.

Usually, at least 10 percent of all girth welds must be tested nondestructively over the entire weld circumference and checked for compliance with weld-quality standards. The requirement of complete radiographic inspection of all girth welds was imposed for the Trans-Alaskan oil pipeline and a similar requirement will be imposed for the Alaska portion of the Alaska Natural Gas Transportation System. However, radiographic interpretation is an inexact science under field conditions, and radiographic re-examination often reveals undetected or misinterpreted flaws whose size exceeds weld-quality standards. Weld flaws that exceed established sizes require repair, an expensive process, unless repair is waived by the Materials Transportation Bureau.

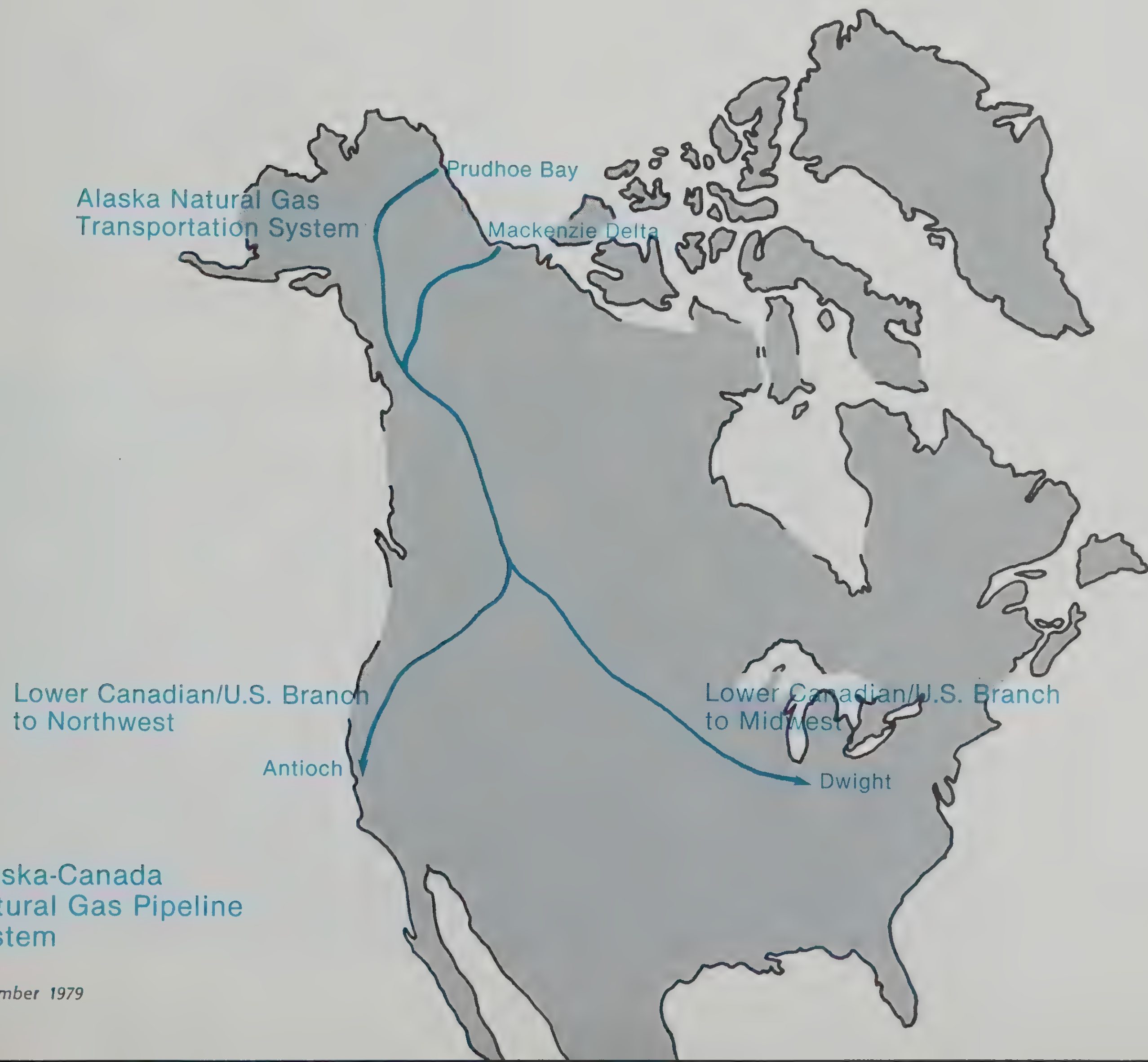
In the Trans-Alaska oil pipeline situation, some sections of the pipe were buried and therefore some questionable girth-weld flaws would have been diffi-

cult to reach for repair. Therefore, MTB was requested to make a judgment in respect to the potential threat to the pipeline's integrity.

MTB decided to assess the extent to which fracture mechanics could aid in making such decisions. They requested direct assistance from the NBS in their assessment of weld quality.

NBS researchers used fracture mechanics techniques to study the influence of loading, crack size, and structural geometry on the fracture resistance of materials containing cracks. When applied to the development of quality standards for pipeline girth welds, the objective of the fracture mechanics analysis was to calculate maximum allowable flaw sizes such that the pipeline operation stresses would not cause flaws of this size or larger to grow through the pipe wall during service. Flaw-size limits were calculated using fracture-mechanics analysis models that relate flaw growth and failure behavior of representative pipeline welds.

Currently, NBS is establishing cooperative programs with the Northwest Pipeline Company (Alaska portion), the Alberta Gas Truck Line Company (Canadian portion), and the Canadian Welding Institute (Canadian pipeline research). Annual workshops will complement the NBS program involving the fracture mechanics and inspection of pipeline girth welds. NBS participants from the NBS Boulder and Gaithersburg facilities include: Dick Reed (project leader); Harry Berger and Len Mordfin (nondestructive evaluation); Harry McHenry, Roland Dewit, and John Smith (fracture mechanics); Dan Chwirut (ultrasonics); Jim Early (mechanical properties); Bud Kasen (fatigue and inspection); Jerry Kruger (corrosion); Bob Placious (radiography); and Sam Schneider (administration).



Alaska-Canada Natural Gas Pipeline System

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"ULTRA-BLACK" COATING FOR HIGH ABSORPTANCE OF SOLAR ENERGY

An NBS scientist has succeeded in developing a simple chemical immersion technique which produces ultra-black surfaces on electroless nickel-phosphorus coatings. Unlike present state-of-the-art techniques, this method does not involve deposition of a black coating. The blackness is associated with a unique surface morphology consisting of a dense array of microscopic conical pores perpendicular to the surface, which act as light traps, capable of absorbing 99.5 percent of incident light. An ultra-black surface can be produced on a variety of materials, such as metals, ceramics, glass, and plastics and may find application in optical and solar devices and possibly as a catalyst because of the large surface area created by the etching.

Christian E. Johnson, Chemical Stability and Corrosion Division, B254 Materials Building, 301/921-3618.

Electroless nickel-phosphorus coatings are commonly applied by the electroplating industry. The process depends on the reduction of nickel ions in solution with hypophosphite—an autocatalytic process. Electroless plating differs in one significant respect from all the other aqueous chemical plating procedures in that it is the only one which does not depend on the presence of a couple between galvanically dissimilar metals. The coating material is commonly considered to be a supersaturated solution of phosphorus in nickel. The phosphorus content is normally about 8 percent by mass, but can be varied between 2 and 12 percent to control strength, ductility, corrosion resistance, and structure.

In this technique, electroless nickel-phosphorus coatings are applied to copper and steel substrates from the acid Brenner bath. To develop the unique surface morphology, the electroless nickel deposits of appropriate composition are immersed in 1:1 concentrated nitric acid and water solution at 50 °C until the blackness appears. The degree of blackness is dependent on the immersion time and the composition of the alloy. The optimum composition and the composition limits have not been determined, but it is judged that an alloy containing 8 percent phosphorus can become ultra-black in about 15-20 seconds. The acid selectively dissolves the coating, leaving a honeycomb structure with pores which extend into the coating and, possibly, through it. This structure can be seen in SEM micrographs in figures 1 and 2. The average maximum pore diameter, pore depth, and pore spacing range from a fraction of a micrometer to several micrometers or about a fraction of a wavelength to several wavelengths of light. Consequently, the pores (which are invisible to the naked eye) trap any incident light causing the surface to appear intensely black, even though the alloy is intrinsically reflective.

Tests of two specimens show that the chemical treatment of the electroless nickel coating can lead to a black surface with an average spectral reflectance of 0.5 percent when measured at wavelengths from 320 to 2140 nm on an Edwards-type integrating sphere spectrophotometer referenced to $BaSO_4$. The results of the spectral reflectance measurements are shown in figure 3.

Analysis of one specimen resulted in an emissivity of approximately 50 percent at room temperature. Qualitative wear resistance was determined by abrading the blackened surface with a pencil eraser which appeared to remove the black surface but which, in reality, was only breaking off the sharp peaks of the etched surface, thus leaving more flat area for light reflection. The conical pores or channels were still present in the coating as revealed by SEM of the abraded area. This coating is mechanically stronger than gold-black, but, in its present state-of-the-art, is fragile enough not to be incorporated where conditions of abrasion or excessive handling would be incurred.

The low spectral reflectance of this coating puts it at or near the top of absorptance capability for any known coating. This capability of the ultra-black surface may find applications in flat

Figure 1—*Scanning electron micrograph of the chemically etched surface of the electroless nickel deposit. This photograph was taken at an angle of 36° from normal to the surface.*

plate solar collectors, optical devices, or may be used in low temperature calorimetry studies. Other possible uses of this unique surface morphology may be on radiometers, light image intensifiers, and because of the large surface area, as a catalyst.

There is a need to determine corrosion resistance, thermal stability and how the formation of the "ultra-black" coating is dependent on the electroless nickel composition and structure. Further tests are being done to characterize the coating properties as a function of the deposition parameters and to gain an understanding of what coating properties affect the absorptivity of the material. Additional work will be required to better measure the emissivity level, to reduce it, and to improve the wear resistance.

A patent application on this technique for obtaining the ultra-black surface has been filed.

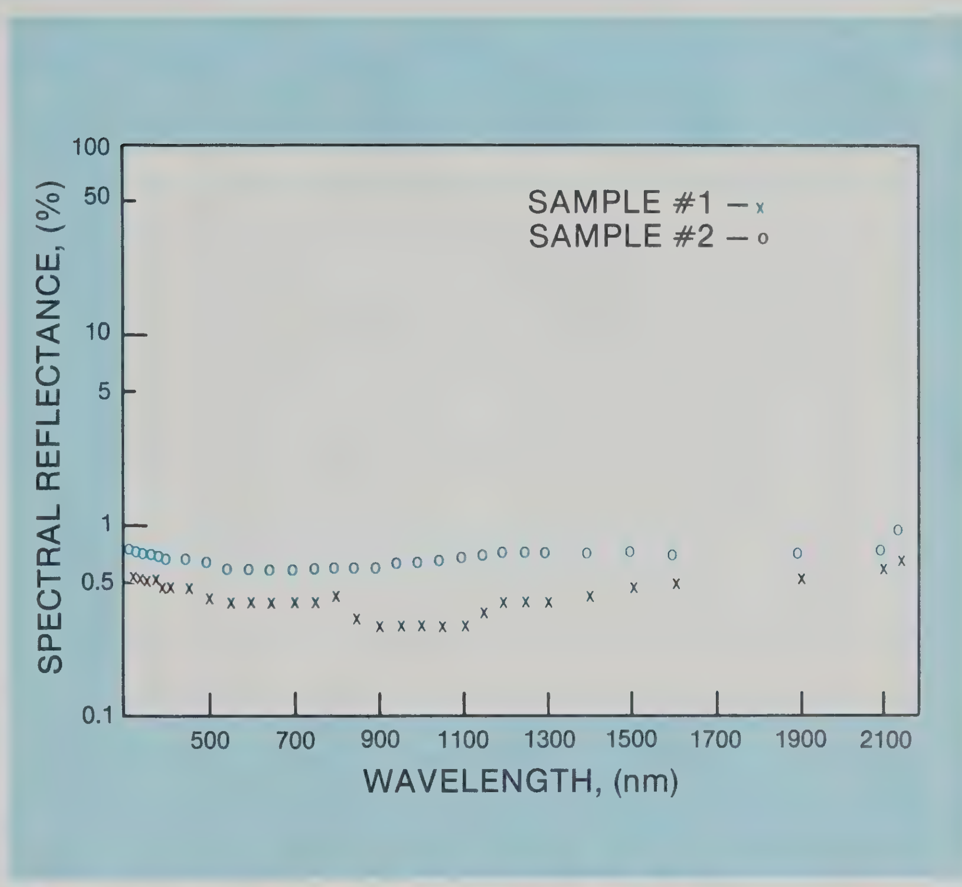
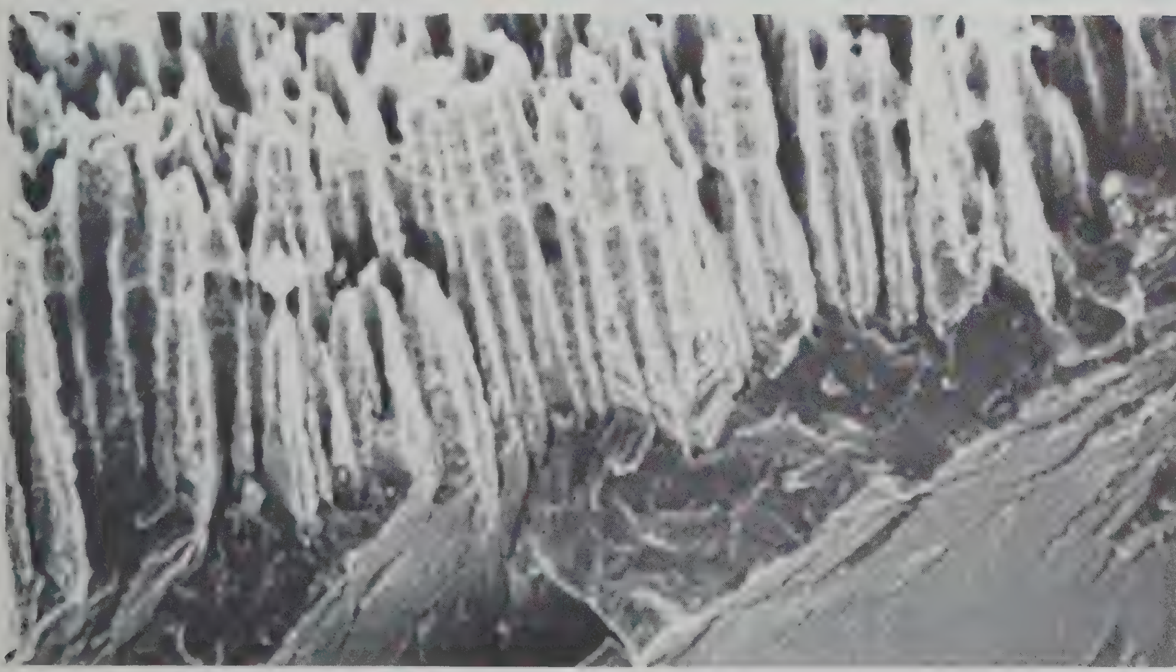


Figure 3—*Spectral reflectance vs. wavelength of light for samples of the chemically etched electroless nickel deposit. Curves are referenced to $BaSO_4$.*

Figure 2—*A scanning electron micrograph, taken at an angle of 72° from normal to the surface, showing the chemically etched surface of the electroless nickel deposit and the remaining bulk of the unetched deposit.*



CONFERENCES

For general information on NBS conferences, contact JoAnn Lorden, NBS Public Information Division, Washington, D.C. 20234, 301/921-2721.

COMPUTER CONFERENCE

Dr. Keith Tocher, British innovator in high-speed electronic computing, statistical modeling, and computer simulation languages will deliver the keynote address at the 1979 Winter Simulation Conference (WSC 79), to be held December 3-5, 1979 in San Diego, California.

A management sciences and computer technology coordinator for the British Steel Corporation, Tocher will describe the work of the Simulation Centre of Britain's Science Research Council and discuss leading computer science issues of concern to simulation specialists on both sides of the Atlantic. Tocher is the author of *The Art of Simulation,* a classic work published in 1963, and has devised computer systems for the British Ministry of Transport and Civil Aviation as well as for the commercial banking network in his country.

Simulation—defined as a tool or technique involving the use of computers to synthesize and analyze models of real world problems—will be discussed at 50 sessions attended by managers, users, practitioners, researchers, and newcomers to simulation. Cosponsoring WSC 79 are: the Commerce Department's National Bureau of Standards; the American Institute of Industrial Engineers; the Association for Computing Machinery's Special Interest Group on Simulation; the Systems, Man, and Cybernetics Society of the Institute for Electrical and Electronics Engineers; the Operations Research Society of America; the College of Simulations and Gaming of the Institute for Management Sciences; and the Society for Computer Simulation.

WSC 79 will be the eleventh such conference, and its contributions will be offered as a bridge to the goals for the next decade, looking toward "an emerging technology of the 1980's that will allow us to harness the power of information processing to tell us why things happen—before they occur." Major areas to be discussed at the conference include computer simulation systems applicable to environmental, health care, transportation, aerospace, and energy problems. Other papers deal with such topics as validation, production planning and control, computer system design and languages, simulation strategies, and crisis management. A sequence of tutorials will map out a path for successful computer modeling in terms of simulation objectives, methodology, analysis, results, and conclusions.

All technical sessions of WSC 79 will be held at San Diego's Holiday Inn Embarcadero. For information on registration, contact Don Warner, Department of Computer Science, California State University, 6000 J Street, Sacramento, CA 95819, phone 916/454-6718.

The conference general chairman is Mitchell G. Spiegel, FEDSIM/NA, Washington, D.C. 20330, phone 202/274-7910. The associate chairman is Paul F. Roth, Department of Energy, Mail Stop 4530, 12th St. and Pennsylvania Ave., N.W., Washington, D.C. 20461 (Roth will be general chairman of WSC 80). The program chairman is Prof. Robert E. Shannon, University of Alabama in Huntsville, School of Science and Engineering, P.O. Box 1247, Huntsville, AL 35807.

CONFERENCE CALENDAR

November 27-29

FIRE SAFETY FOR THE HANDICAPPED, NBS, Gaithersburg, MD; sponsored by NBS and HEW; contact: B. Levin, A363 Polymers Building, 301/921-3175.

December 3-5

1979 WINTER SIMULATION CONFERENCE, San Diego, CA; sponsored by NBS, AIIE, ACM, IEEE, ORSA, TIMS, and SCS;

December 10-11

RESEARCH OPPORTUNITIES IN RESOURCE RECOVERY, NBS, Gaithersburg, MD; sponsored by NBS, DOE, NSF, and National Center for Resource Recovery; contact: Joseph Berke, B326 Physics Building, 301/921-2343.

NBS-NCSBCS JOINT CONFERENCE ON BUILDING REHABILITATION RESEARCH AND TECHNOLOGY FOR THE 1980's, Jack Tar Hotel, San Francisco, CA; sponsored by NBS and NCSBCS; contact: Sandra Berry, B226 Building Research Building, 301/921-2776.

December 12

COMPUTER NETWORKING SYMPOSIUM, NBS, Gaithersburg, MD; sponsored by NBS and IEEE; contact: Fran Nielsen, B212 Technology Building, 301/921-2601.

1980

May 5-7

TOPICAL CONFERENCE ON BASIC OPTICAL PROPERTIES OF MATERIALS, NBS, Gaithersburg, MD; sponsored by NBS in cooperation with OSA; contact: Albert Feldman, A251 Materials Building, 301/921-2840.

****May 13-15**

MEDILOG 80, NBS, Gaithersburg, MD; sponsored by NBS and DOD; contact: Charles Hulick, A740 Administration Building, 301/921-3465.

*** Conference originally scheduled for October 31-November 2, postponed to May 13-15, 1980.*

PUBLICATIONS

VIBRATION ISOLATION

*Vibration Isolation: Use and Characterization, Snowden, J. C., Nat. Bur. Stand. (U.S.), Handb. 128, 129 pages (May 1979) Stock No. 003-003-02065-6, $4.**

The National Bureau of Standards' Center for Mechanical Engineering and Process Technology has published a new state-of-the-art handbook on the theory and practice of vibration isolation for machinery.

Written by Dr. John C. Snowden of Pennsylvania State University under NBS sponsorship, *Vibration Isolation: Use and Characterization* is a practical guide for engineers who design and use vibration isolation systems, and for the scientists who research new systems.

Unwanted vibration from machinery can lead to a number of problems, from excessive noise levels and difficulties in process control to structural damage and loss of product quality. Snowden's text examines solutions to this problem based on approaches which isolate the source of vibration with various support systems.

Synthesizing the results of over 200 separate references, Snowden discusses the mechanical properties of vibration damping materials, analyses of various classes of antivibration mounting systems, and methods for testing and evaluating the performance of antivibration mountings.

** Publications cited from this point on may be purchased at the listed price from the U.S. Government Printing Office, Washington, D.C. 20402 (foreign: add 25%). Microfiche copies are available from the National Technical Information Service, Springfield, VA 22161. For more complete periodic listings of all scientific papers and articles produced by NBS staff, write: Editor, Publications Newsletter, Administration Building, National Bureau of Standards, Washington, D.C. 20234.*

MOBILE HOME FIRE SAFETY IMPROVEMENTS

Mobile Home Fire Studies: Summary and Recommendations (NBSIR 79-1720), Budnick, E. K., Klein, D. P. Order by PB #293 527, 94 pages, $6.00, National Technical Information Service, Springfield, VA 22161.

Recommendations for improving the levels of fire safety in mobile homes are set out in a report issued by the National Bureau of Standards' Center for Fire Research.

The recommendations, part of a five-year cooperative research program sponsored by NBS and the Department of Housing and Urban Development (HUD), are designed to help upgrade the Federal Mobile Home Construction and Safety Standards.

Most residential fires are initially localized and small, but the room size and layouts and combustible interior finishes usually found in mobile homes offer the potential for rapid fire growth and spread. These two characteristics—room geometry and interior finish—were among the major factors NBS researchers investigated in 90 full-scale fire tests conducted in the kitchens, corridors, living rooms, and bedrooms of fully instrumented mobile homes. The tests were conducted at NBS over the past four years.

The homes tested had structural material and spatial characteristics comparable to those found in mobile homes currently being constructed to comply with the HUD standard. Analyses of the tests were directed at evaluating the extent of the potential hazard to life and/or property damage occurring in each of the tests. High temperature, excessive carbon monoxide from the fire, and oxygen deficiency were the factors used to judge the hazard to life. The attainment of flashover was the criterion for property damage. Flashover is a phenomenon in which heat from the upper walls and ceiling and the hot gases and smoke layer in the upper part of the room suddenly cause the room to become fully involved in flames.

The Bureau's recommendations for upgrading the level of fire protection covers the kitchen range area, where cooking fires are likely, and the wall and ceiling finish materials throughout the mobile home, since those surfaces could serve as a means of rapid flame spread.

For mobile home kitchens, NBS developed specifications for steel hoods above the cooking ranges to prevent overhead cabinets from igniting. Requirements for flame resistance of the exposed undersides of the cabinets and the walls behind the range were also established.

A series of recommendations regarding the flame spread ratings of interior finishes in the form of several design options were also developed by NBS. Each of the design options would reduce the likelihood of flashover for a different set of conditions. The options were identified as not resulting in flashover during the full-scale tests. Preliminary estimates of the impact of these more stringent design options—in terms of the number of mobile home fires that could have been less severe if the options were in effect in 1977—were also made by Bureau analysts. This limited impact analysis is based on the likely effect on fire severity, and does not include an economic analysis.

NBS has transmitted the recommendations to HUD for consideration in that agency's ongoing review of the mobile home safety standard, which was established in 1976. This mandatory standard adopted many of the provisions in an existing voluntary consensus standard established by the National Fire Protection Association and utilized by many mobile home manufacturers and state and local regulatory officials. The NBS tests suggest limitations on the usefulness of some of the current fire safety criteria called for by that standard.

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DETERMINATION OF POTASSIUM IN SERUM

A Reference Method for the Determination of Potassium in Serum, Velapoldi, R. A., Paule, R. C., Schaffer, R., Mandel, J., Machlan, L. A., and Gramlich, J. W., Nat. Bur. Stand. (U.S.), Spec. Publ. 260-63, 104 pages (May 1979) Stock No. 003-003-02068-1, $3.75.

Guided by a committee of experts in clinical chemistry, a reference method was established for the determination of serum potassium based on flame atomic emission spectroscopy (FAES). Its accuracy was evaluated by comparing the values obtained by use of the method in 12 laboratories against the results obtained by a definitive analytical method based on isotope dilution-mass spectrometry (IDMS). Seven serum pools with potassium concentrations in the range 1.319 to 7.326 mmol/L were analyzed. Manual and semiautomated pipetting alternatives were tested using sample sizes of 5.0 and 0.25 mL, respectively.

The laboratories used several different FAES instruments. The results showed that the standard error for a single laboratory's performance of the procedure ranged from 0.049 to 0.063 mmol/L with a maximum bias of 0.065 mmol/L over the range of concentrations studied. These values were within the accuracy and precision goals that had been set by the committee. The results from the two pipetting techniques were similar. The calibration curve data showed excellent linearity over the total concentration range, with 20 of 22 curves having standard deviations of fit 0.075 mmol/L or less.

With appropriate experimental design, the reference method may be used to establish the accuracy of field methods as well as to determine reference potassium values for pooled sera.

NEW GUIDE TO FEDERAL CALIBRATION LABS

Catalog of Federal Metrology and Calibration Capabilities, Leedy, K. D. Nat. Bur. Stand. (U.S.), Spec. Publ. 546, 1979 Edition, 52 pages (June 1979) Stock No. 003-003-02082-6, $2.50.

The National Bureau of Standards has published the first issue of a detailed *Catalog of Federal Metrology and Calibration Capabilities.*

Produced by a comparatively new NBS group, the Precision Measuring and Test Equipment Project, the Catalog will eventually list most metrology and calibration laboratories in the Federal Government. The U.S. General Accounting Office estimates the value of precision testing equipment owned by the Federal Government at over $2.7 billion. More than $250 million per year is spent in calibrating this equipment.

The first issue of the catalog indexes laboratories from the Departments of Defense, Energy, and Transportation and the National Aeronautics and Space Administration. Subsequent editions will add other Federal calibration facilities. The laboratories are cross-indexed by agency and geographical location. Entries describe the particular measurement capabilities of each laboratory and provide the name and telephone number of an information contact.

The Precision Measuring and Test Equipment (PMTE) Project was begun at NBS in 1978 in response to a request from the Office of Management and Budget for an NBS program to improve the management and use of precision test equipment by the Federal Government.

The PMTE project works to improve communications between Federal PMTE laboratories and to identify useful technologies and management strategies for the laboratories. Those interested in receiving news of the PMTE project, including publications and meetings, may receive the project newsletter, *PMTE Update*. For information, contact the PMTE Project, Office of Measurement Services, National Bureau of Standards, Washington, D.C. 20234, 301/921-2805.

STANDARD REFERENCE MATERIAL 1470

SRM 1470: Polyester Film for Oxygen Gas Transmission Measurements, Barnes, J. D., and Martin, G. M., Nat. Bur. Stand. (U.S.), Spec. Publ. 260-58, 43 pages (June 1979) Stock No. 003-003-02077-0, $2.

This report presents information which should be of interest to users of NBS Standard Reference Material 1470. This SRM takes the form of 23 μm thick sheets of poly(ethylene terephthalate) film. The gas transmission rates of these films with respect to oxygen gas have been carefully analyzed. We describe where the film comes from, how it is packaged, and how it should be conditioned prior to measuring. The steps which were taken to characterize a random sample of sheets from the production lot of the SRM are discussed in detail. The gas transmission rates and the time-lags of 22 films were measured using a state-of-the-art electronic manometric permeation facility. The temperature dependence of the permeability was determined over the temperature range 288 K to 310 K. A small pressure effect was found which is thought to be an artifact. The statistical measures which were derived from the data are discussed in detail. It is concluded that the largest source of variability is from one sample to another with a coefficient of variation amounting to 4 percent. A brief discussion of units for expressing permeabilities is given. Effects due to thermal conditioning ("aging") and outgassing are discussed.

Analytical Chemistry

Hertz, H. S., and Chesler, S. N., Ed., Trace Organic Analysis: A New Frontier in Analytical Chemistry. Proceedings of the 9th Materials Research Symposium held at the National Bureau of Standards, Gaithersburg, MD, Apr. 10-13, 1978, Nat. Bur. Stand. (U.S.), Spec. Publ. 519, 788 pages (Apr. 1979) Stock No. 003-003-02054-1, $14.

Computer Science and Technology

Cotton, I. W., Computer Science and Technology: Measurement of Interactive Computing: Methodology and Application, Nat. Bur. Stand. (U.S.), Spec. Publ. 500-48, 111 pages (June 1979) Stock No. 003-003-02081-8, $4.

Health and Safety

Carson, D. H., Archea, J. C., Margulis, S. T., and Carson, F. E., Safety on Stairs, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 108, 122 pages (Nov. 1978) Stock No. 003-003-02026-5, $3.

Linzer, M., Ed., Ultrasonic Tissue Characterization II. A Collection of Reviewed Papers Based on Talks Presented at the Second International Symposium on Ultrasonic Tissue Characterization held at the National Bureau of Standards, Gaithersburg, MD, June 13-15, 1977, Nat. Bur. Stand. (U.S.), Spec. Publ. 525, 339 pages (Apr. 1979) Stock No. 003-003-02058-3, $5.50.

Robertson, E. M., Juror Response to Prerecorded Videotape Trials, Nat. Bur. Stand. (U.S.), Spec. Publ. 480-30, 28 pages (June 1979) Stock No. 003-003-02071-1, $1.75.

Schafft, H. A., Ed., Semiconductor Measurement Technology: Reliability Technology for Cardiac Pacemakers III—A Workshop Report. Report of a Workshop held at the National Bureau of Standards, Gaithersburg, MD, Oct. 19-20, 1977, Nat. Bur. Stand. (U.S.), Spec. Publ. 400-50, 134 pages (June 1979) Stock No. 003-003-02076-1, $4.50.

Velapoldi, R. A., Paule, R. C., Schaffer, R., Mandel, J., Machlan, L. A., and Gramlich, J. W., Standard Reference Materials: A Reference Method for the Determination of Potassium in Serum, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-63, 104 pages (May 1979) Stock No. 003-003-02068-1, $3.75.

Electromagnetic Metrology

Montgomery, J. P., and Chang, D. C., Electromagnetic Boundary-Value Problems Based Upon a Modification of Residue Calculus and Function Theoretic Techniques, Nat. Bur. Stand. (U.S.), Monogr. 164, 183 pages (June 1979) Stock No. 003-003-02075-3, $5.

Energy Conservation and Production

Park, C., Mulroy, W. J., and Kelly, G. E., A Study of the Dynamic Flue-Gas Temperature and Off-Period Mass Flow Rate of a Residential Gas-Fired Furnace, Nat. Bur. Stand. (U.S.), Tech. Note 999, 41 pages (July 1979) Stock No. 003-003-02092-3, $2.

Reppert, M. H., Ed., Summer Attic and Whole-House Ventilation, Proceedings of a Workshop held on July 13, 1978 at the National Bureau of Standards, Gaithersburg, MD, Nat. Bur. Stand. (U.S.), Spec. Publ. 548, 153 pages (July 1979) Stock No. 003-003-02089-3, $4.75.

Failure Analysis

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NEWS BRIEFS

X-RAY MAGNIFIER, DEEP OCEAN SAMPLER, LASER GLASS WIN IR-100's. NBS researchers have been cited in three of this year's "IR-100" awards from Industrial Research/Development magazine for the "100 most significant new technical products of the year." The three awards were for: an X-Ray Magnifier which provides a 25-fold improvement in the resolution of real-time x-ray images; a Deep Ocean Sampler with which microbiologists can retrieve water samples from the deepest parts of the ocean and maintain them at their original temperature and pressure; and a specially formulated neodymium-doped fluorophosphate glass for use in high energy lasers that shows a 50 percent improvement in the non-linear refractive index over conventional laser glasses. The first two awards were made to NBS, while the third was shared with a group from Lawrence Livermore Laboratory; Hoya Optics, USA; Owens-Illinois; and Schott Optical Glass, Inc.

PRECISION MEASUREMENT GRANTS FOR 1981. NBS is currently soliciting proposals for two research grants. The grants are for one year but may be renewed for up to two additional years. NBS Precision Measurement Grants are awarded each year to scientists in academic institutions for work in the field of precision measurements and the determination of fundamental physical constants. Prospective candidates must submit information to NBS by February 15, 1980 through September 1981. Information on how to apply can be obtained from: Dr. Barry N. Taylor, B258 Metrology Building, NBS, Washington, D.C. 20234.

INDUSTRIAL THERMOMETER TESTING. The NBS Office of Measurement Services and the Temperature Measurements and Standards Division are now seeking participants for a new Measurement Assurance Program (MAP) for testing industrial platinum resistance thermometers. The program will use the new standard for testing PRT's issued by ASTM Committee E-20 on Temperature Measurement, Subcommittee on Resistance Thermometers. Interested parties should contact Dr. George Furukawa, B310 Physics Building, NBS, Washington, D.C. 20234.

COLOR DISTORTION OF LIGHTING SYSTEMS, SAFETY PROBLEMS. Color distortion and related safety problems presented by new, more efficient light sources are being studied in two new research laboratories set up at the NBS Center for Building Technology (CBT). The labs are being used to carry out a series of experiments to determine which colors look red, green, or blue, for instance, when an object or area is illuminated by one of the more energy-efficient type of lights now available or being developed. NBS will make recommendations to ensure that various safety colors look as they should when viewed under different light sources. The work is being carried out with support from the U.S. Occupational Safety and Health Administration.

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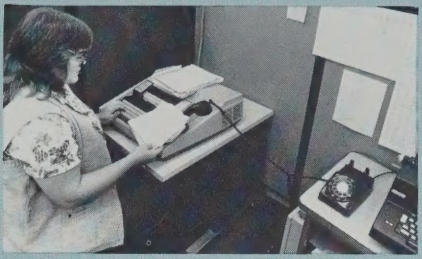

Are citizen rights being protected in automated handling of personnel records? A Columbia University professor conducted an in-depth study of this problem for NBS and the Privacy Protection Study Commission. Learn the results in the next issue of DIMENSIONS/NBS.

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